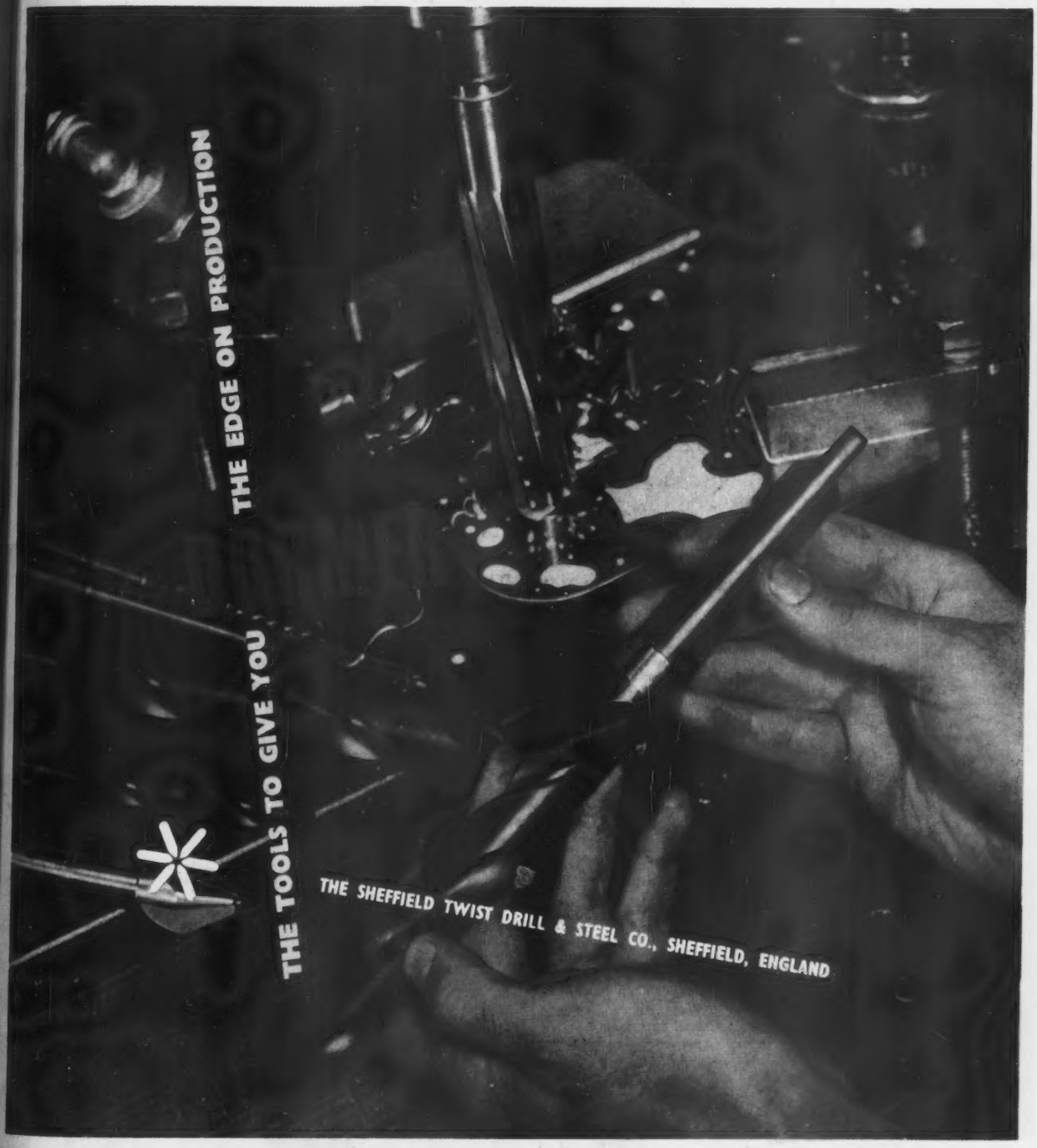
AUTOMOBILE ENGINEER

UNIVERSITY OF MICHIGAN

DESIGN · PRODUCTION · MATERIALS

Vol. 47 No. 4 APRIL 1957 PRICE: 3s. 6d.

ENGINEERING LIBRARY



T19

Atlas Copco air tools at work on the Bristol Britannia

British aircraft factories are working at top pressure to satisfy the growing demand for British military and civil airliners; vigorous effort on the assembly line calls in turn for tools that will stand up to long periods of continuous work without servicing, tools that are robust and hard-wearing—yet capable of high-precision performance.

An Atlas RAB 200 UR reversible pneumatic screwdriver being used on leading edge section of a wing of the Bristol Britannia.

Atlas Copco pneumatic tools are specially designed with this end in view. At the Bristol Aeroplane Company's factory, hundreds of Atlas tools are busily at work, many of them on the world-famous Britannia which recently made its first scheduled flight.

The Bristol Company is only one of many concerns who have found that you can't beat Atlas Copco air tools; their reliability in action and economical power/weight ratio is making them increasingly popular with aircraft manufacturers all over the world.

World-wide sales and service

The Atlas Copco Group puts compressed air to work for the world. It is the largest group of companies specialising solely in the development and manufacture of compressed air equipment. It embraces Atlas Copco companies or agents manufacturing or selling and servicing Atlas Copco equipment in ninety countries throughout the world.

For further details about Atlas Copco equipment, contact your local Atlas Copco Company or Agent, or write to Atlas Copco AB, Stockholm 1, Sweden, or Atlas Copco (Great Britain) Limited, Beresford Avenue, Wembley, Middlesex.

Atlas Copco

Manufacturers of Stationary and Portable Compressors, Rock-Drilling Equipment, Loaders, Pneumatic Tools and Paint-Spraying Equipment

AUTOMOBILE ENGINEER

CONTENTS

CHOICE OF LUBRICANTS IS DISCUSSED IN AN ARTICLE IN THIS ISSUE; THIS ILLUSTRATION IS OF HARDENED AND CRACKED GREASE IN A ROAD WHEEL HUB

127 Editorial *Geneva*

128 David Brown S550 Gearbox *A five-speed constant mesh helical gear transmission unit, with direct or overspeed top gear and synchronizers for four of the forward speeds*

133 Fuels and Lubricants C. G. Tresidder *Part II: Choice of lubricants to suit design and operating conditions*

141 Foreign Publications *Brief reviews of current technical books*

143 The Fuess Metal Spectroscope R. H. Tyas *A new visual instrument for routine production control*

146 The Pneumatic Governor Dr. Charles R. Webb *Mode of operation and advantages of this system for application to compression-ignition engines*

152 Opposed-Piston Oil Engines R. Waring-Brown *A brief survey of units with rocker-actuated crankshafts*

156 Preferred Numbers J. L. Koffman *Theory and practical application to the selection of ranges of sizes of products*

159 Wimet Econotip Tools *Throw-away carbide tip eliminates re-servicing and reduces idle time*

161 The Hookes Joint W. Steeds *Its mechanics analyzed by the use of simple trigonometry and ordinary descriptive geometry*

164 The Euco Micrometric Spacer *A device for the precise adjustment of the width of interlocking milling cutters*

165 Current Patents *A review of recent automobile specifications*

Published the second Wednesday in every month by ILIFFE & SONS LIMITED
*Dorset House, Stamford Street, London, S.E.*1.
Telephone · Waterloo 3333 (60 *lines*)
Telegrams · Sliderule, Sedist London.
The annual subscription inland and overseas is £2 17*s.* 0*d. including the special number Canada and U.S.A.* $8·50

BRANCH OFFICES
Coventry · 8-10 *Corporation St.*
Telephone · Coventry 5210
Birmingham 2 · *King Edward House, New St.*
Telephone · Midland 7191-7
Manchester 3 · 260 *Deansgate*
Telephone · Blackfriars 4412
*Glasgow, C.*2 · 26B *Renfield St.*
Telephone · Central 1265-6

VOLUME 47 **NUMBER 4** **APRIL 1957**

The Conquest of Friction

Leonardo da Vinci, that versatile genius of the Renaissance, studied friction in many of its aspects, being the first to distinguish between sliding and rolling friction. He also remarked upon the importance of polishing the surface of parts that move in a groove or around a pivot. Among his many manuscripts are sketches of several ingenious anti-friction bearings which he described as 'pivots of the highest perfection' and mechanisms whose motion, once started, were declared to be 'wonderful and supernatural in duration'. Some of these are known to have had practical application. Hundreds of years later many more of da Vinci's theories were to find practical expression and further development with the foundation of SKF and the introduction of a unique range of anti-friction bearings for many different purposes.

THE SKEFKO BALL BEARING COMPANY LIMITED · LUTON · BEDS

THE ONLY BRITISH MANUFACTURER OF ALL FOUR BASIC BEARING TYPES: BALL, CYLINDRICAL ROLLER, TAPER ROLLER AND SPHERICAL ROLLER

G151

SKF

Editor *J. B. Duncan*

Editorial Staff *T. K. Garrett, A.M.I.Mech.E.* *A.F.R.Ae.S.(Associate Editor)*

F. C. Sheffield

DESIGN MATERIALS **AUTOMOBILE ENGINEER** PRODUCTION METHODS WORKS EQUIPMENT

Geneva

In view of the current negotiations in respect of the formation of a common European market, the Geneva Motor Show this year assumed even greater significance than hitherto. Since, in Switzerland, all car manufacturers compete on more or less equal terms, the degree of success achieved by exhibitors in this Show is, to some extent, an indication of what their prospects would be in a free European market. However, due consideration must be given to the fact that the terrain and climate of Switzerland are so different from those in many other countries.

Apparently the surest way to maintain a firm footing in highly competitive markets is to provide at relatively frequent intervals models with new features, particularly so far as styling is concerned. To do so without appreciably increasing costs is one of the most difficult problems that manufacturers have to face. In the United States of America, of course, this is achieved by what, in that country, are termed face-lifting measures; these involve the exercise of considerable ingenuity in altering bodies in such a way as to call for a minimum of retooling.

In the coachbuilders' section of the Geneva Show some positive trends could be discerned. The wrap-round type of windscreen is becoming increasingly popular, despite the fact that the problem of wiping the wrapped-round portion in wet weather still remains to be solved. By comparison with the earlier wrap-round layouts adopted by the American designers, great improvements have been made by the European coachbuilders.

One of these improvements is the blending of the lower edge of the wrap-round portion of the screen into the waist-line, which is continued over the full length of the vehicle by a line pressed in the crowns of the front and rear wing panels. This helps in the harmonization of the general lines of the screen with those of the body. Several methods have been employed to avoid the incongruity of a forward-raked screen pillar. One of these is the adoption of a relatively small wrap-round, thereby avoiding the forward rake altogether. This has the advantage that the wipers can be made to sweep a relatively large proportion of the screen. Where the forward-raked pillar has been adopted, the angle of the rake is generally not so pronounced as on some of the American cars and is thus more readily harmonized with the lines of the roof and the pillars of the doors and rear quarters.

Most of the European manufacturers have now abandoned the traditional form of radiator grille, because it cannot readily be incorporated in the modern form of body design. The latest Lancia models with bodies by Pinin Farina have a shield representing the Lancia radiator grille, mounted in some instances at the front of the bonnet-surround and in others on the grille in the radiator air-intake opening. On a number of cars, the body sides incorporate the dihedron angle treatment discussed at some length in the July 1956 issue of *Automobile Engineer*. A merit of this arrangement is the avoidance of chromium plated adornment.

There were not many new mechanical features on show. A horizontally-opposed, four-cylinder, four-stroke engine has been introduced by Goliath. Presumably this type of power unit will have a wider appeal than the two-stroke engine that this manufacturer has had in production for some years. The recently developed suspension system for the Mercedes Benz 300SL Roadster is a straw in the wind, indicating that manufacturers are still exploring possible ways of improving their rear suspensions, without adding too much to the cost. This system appears to have some features in common with that used on the Soletta car, described in the December 1956 issue of *Automobile Engineer*. An interesting development in the field of transmissions is the Saxomat centrifugal-and-vacuum clutch system, which is not unlike the Standard Newton-drive arrangement. Electric control and preselection are the principal novelties of the Selektromat transmission.

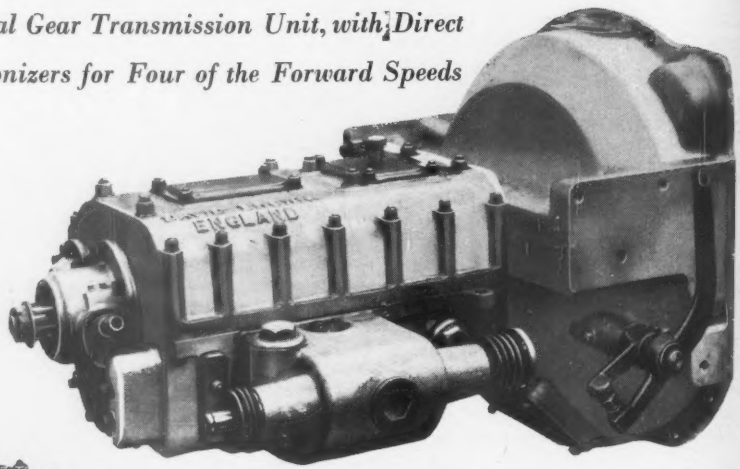
Some new small car models were exhibited. Among the interesting features of these cars is the adoption of the gull-wing type of door on the British Frisky and on a small Abarth Fiat 750, with coachwork by Vignale. A disadvantage of this type of door is that when it is opened, pedestrians and drivers of passing vehicles may be presented with only an edge-on view and therefore may not see it. This could be dangerous. Possibly this disadvantage could be overcome by employing a combined hinge-and-lock mechanism on each side, so that the whole canopy could be lifted, in a manner similar to the arrangement of the bonnet lid on the early models of the current Vauxhall Velox and Wyvern designs.

The tiny Vignale car, based on the rear-engine layout, has no bonnet at the front. This arrangement, although strikingly unconventional by current standards, would be a logical development for rear-engined cars, if it were possible thereby to seat the occupants further forward to improve the weight distribution and range of vision.

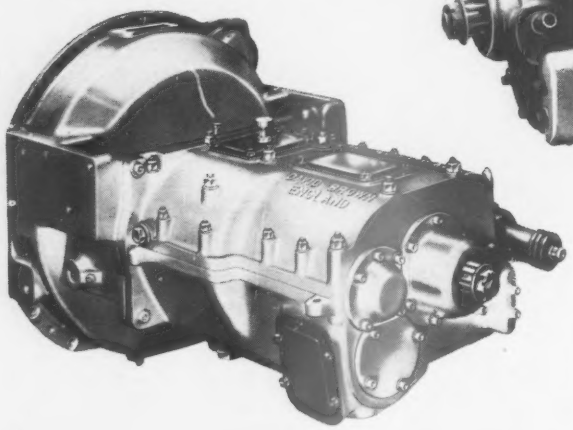
In general, the styling of the latest British quantity-produced cars compares favourably with that of their Continental counterparts and even with the exhibits in the coachwork section. Great interest was shown in the new British models, and it would appear that, provided the competition to be faced is fair so far as the economic background is concerned, our manufacturers can more than hold their own in a free market in Europe.

David Brown S550 Gearbox

A Five-Speed Constant Mesh Helical Gear Transmission Unit, with Direct or Overspeed Top Gear and Synchronizers for Four of the Forward Speeds



To provide adequate stiffness and to prevent leakage of oil, substantial flanges are incorporated at the joint faces round the aluminium alloy casing



A FIVE-SPEED constant mesh gearbox, designated the S550 unit, has recently been added to the heavy-duty range produced by David Brown Industries Ltd., Automobile Gearbox Division, Park Works, Huddersfield. The overall dimensions of this unit have been kept within the normal limits of those of the existing models, despite the fact that four of the forward speeds have synchronizing mechanisms —the first speed and reverse gears are not synchronized. This degree of compactness has been retained largely by virtue of the adoption of the Porsche method of gear speed matching.

The Porsche system embodies friction cones having limited independent rotational movement, whereby a servo effect is obtained, so that effort at the gear lever for engagement of the mating elements is much reduced. A noteworthy feature is that the axial dimensions of this synchronizing device are no greater than those of a conventional dog clutch; consequently, the overall length of the complete gear assembly is not increased by the incorporation of the synchronizers. Moreover, the diameter of the synchronizing units is not large enough to influence the spacing of the mainshaft and layshaft. The overall dimensions of the unit, excluding the gear selector lever tower and the bellhousing, are: 18⅛ in long, 18 in wide and 13 in deep. With the gear selector assembly, its dry weight is approximately 300 lb. The forward control assembly, together with its coupling shaft and universal joints, weighs an additional 30 lb.

A feature, which is shared with several other units in this manufacturer's range of gearboxes for transport vehicles, is the placing of the layshaft and mainshaft side-by-side, the casing being split in a horizontal plane at the level of the axes of the shafts. This arrangement greatly simplifies assembly. The bores in which the bearing housings are carried are machined with the halves of the casting bolted together and, to minimize the effects of differential expansion, steel liners are fitted in these bores. Accurate location of the two parts of the casing is effected by the liners instead of by dowels.

Both the main castings are of aluminium and are substantially flanged for stiffness and to ensure that the joints are oil-tight. A flange width of approximately ¾ in has been adopted, and the abutting faces constitute a metal-to-metal joint, sealed on assembly by a jointing compound. Effectiveness of the measures for oil retention is particularly important, because in certain applications the box is mounted with the joint in the vertical plane.

Twenty studs hold the two parts of the casing together. Eleven ⅜ in diameter high tensile steel studs are screwed into the joint face of the lower half of the case, at approximately 3 in intervals along the side flanges. They extend through deep bosses on the mating half of the case. At each end, and at the transverse web, there are three ½ in diameter studs suitably spaced to clamp the castings firmly round the housings for the end and intermediate bearings of the two shafts. The Unified Screw Thread system has been adopted throughout, U.N.C. threads being used at the ends that are screwed into aluminium and U.N.F. at the ends on which the nuts are fitted. This Standard is now being adopted in all the new designs of David Brown automobile gearboxes. Self-locking nuts of the fibre or nylon insert type are employed; they help to prevent oil leakage that may occur through the bolt holes and past the threads.

The bellhousing, which houses the clutch withdrawal shaft, is also an aluminium casting. Bolts and nuts are used to pull it up against a machined face on the front of the gearbox assembly. This method of attachment is employed because it enables the box to be removed readily from a vehicle chassis, without disturbing adjacent components. If studs were to be used, chassis designers would have to allow for much more axial movement of the box to enable it to be pulled clear. The arrangement also facilitates employment of non-standard bellhousings. On top of the upper half of the gearbox are two pressed steel inspection covers, one of which carries a ventilator. In the lower half and facing towards the near-side, is a standard flanged aperture for the attachment of a power take-off; when not used for this purpose, it is covered by a pressed steel plate. A similar aperture is provided beneath the box to provide an alternative take-off position. The oil filler and dipstick is incorporated in the separate casting that houses the gear selector mechanism in the lower half of the casing. There is

a large drain plug at the lowest level of the base. Provision is made for alternative filler and drain holes to meet the different requirements when the box is mounted with the gear shaft axes in the vertical plane and when it is installed in the inverted position for left-hand drive vehicles.

The manufacturers recommend that S.A.E. 90 oil should be used, and the capacity is 3 gallons. Distribution of the lubricant is effected by splash. This system of distribution is fully effective, since the larger gears on both shafts dip below the level of the oil in the sump and there are no plain bearings. All the floating pinions on the mainshaft are carried on roller bearings, while the shafts themselves, including the reverse shaft, run in ball or roller bearings. To ensure adequate supply of lubricant to the rollers of the loose pinions, there is a series of radial holes drilled from between the roots of the teeth to the bore. Oil leakage from the front end of the primary shaft is checked by a long retainer scroll. At the rear, there is a synthetic rubber oil seal of the double-lipped, or back-to-back, variety at the output coupling end of the mainshaft.

Gear changing is effected by the usual arrangement of three rods and selector forks with conventional ball-and-pin interlock and spring-loaded detent plungers. The forward-control rod is mounted in bearings housed in a casting bolted to the off-side of the lower half of the box. This layout is suitable for application to most British forward-control vehicles. Connection to the driver's gear change lever is effected by means of a single sliding and oscillating shaft, which has a small, Hardy-Spicer universal joint at each end so that a considerable range of alignment angles can be accommodated.

To meet the needs of left-hand drive vehicles, a near-side control can be provided by the simple expedient of turning the entire box upside down, thus bringing the layshaft to the off-side of the mainshaft. Since, in this condition, the flange studs hang downwards, the oil-retaining characteristics of the type of lock nut used are important.

Yet another variation can be made, to provide for a central gear-change control, with a directly-mounted lever. In this type of application, the box is turned through 90 deg only, so that the axes of its shafts are in a vertical plane. This places the selector tower in an upright position, so that it can carry a long gear lever instead of the short one associated with remote control layouts. The arrangement of the fixing bolts and studs in the bellhousing is such as to accommodate these alternative positions of the box.

A range of five speeds is provided, the top gear being either direct or overspeed, as required. The box has been designed for a torque input of 300 lb-ft, and in the direct-drive form it is suitable for vehicles of up to 20 tons gross weight. With the overspeed gear, it is intended for passenger vehicles, particularly high-speed coaches, and for those classes of goods transport where loading is relatively light but where sustained high cruising speeds are called for.

Selection of 300 lb-ft as the torque capacity was made with regard to the characteristics of widely used proprietary engines and the vehicle classes associated with them. The 5LW Gardner unit, the output of which is 300 lb-ft, and the Perkins R6, with an output of 240 lb-ft, are both popular power units for a diversity of transport vehicles. To have provided for the greater torque capacity of engines, such as the 6LW Gardner, giving a torque output of 358 lb-ft, would have placed the unit, so far as size and weight are concerned, in a class of gearboxes larger than that acceptable to many vehicle builders and would, therefore, have reduced the range of its appeal to the vehicle assembling section of the industry.

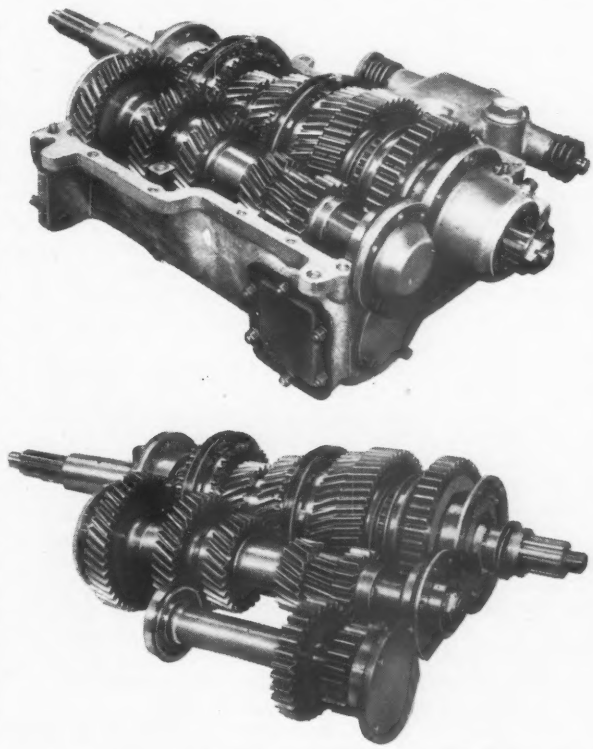
Apart from the mainshaft, all the running components are of En 36 steel, gas carburized and case hardened all over. The mainshaft is of En 39 steel, heat treated to give a tensile strength of 85-90 ton/in^2. All the gears are in constant mesh; they are of the single helical type, except the reverse set, which have straight teeth to avoid continuous axial loading of the reverse shaft bearings.

A 7 d.p. hob is used to form the forward speed gears, the helix angle varying progressively, from 27 deg 40 min to 9 deg 42 min, to balance the gear thrust. Cutting is done on David Brown Hydrax machines, and is followed by shaving. The tooth form provides a 20 deg pressure angle, with corrections to give maximum strength. Also, profile modifications are made to avoid tip interference under excessive load. All the straight-tooth reverse and power take-off gears are of 6 d.p.

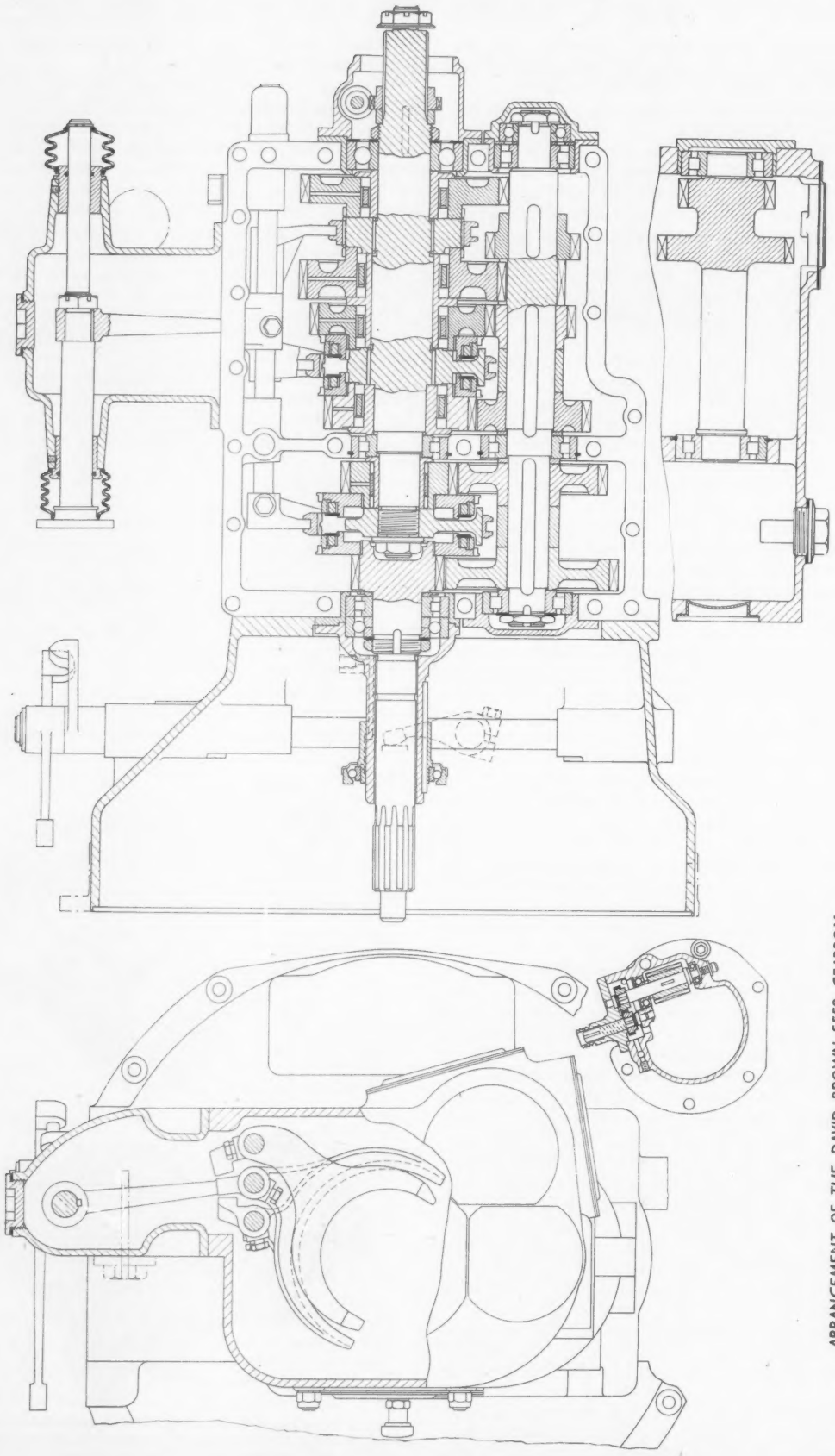
The input shaft is a little over 14½ in long, and its maximum diameter, of 1⅞ in, is adjacent to the integral 19 tooth, constant mesh pinion. A parallel-roller single-row bearing takes the journal loads. It is backed by a single-row ball bearing of the duplex inner race type. The outer race has slight diametral clearance in its housing; this ensures that only thrust forces are applied to the balls.

A 21 in long mainshaft is employed. Its maximum diameter is 2⅝ in and, towards the rear, it is reduced to 2 in diameter to carry the reverse gears and the single-row deep-groove ball bearing. This bearing locates the shaft axially and reacts the thrust. In front of the maximum diameter portion, the shaft is reduced to 1¾ in diameter, to receive the single-row roller bearing in the intermediate web.

The layshaft is 19¾ in long and carries an integral 15-tooth first gear pinion. Its maximum diameter is 1⅞ in, and it is reduced to 1¾ in diameter where it carries the inner race of the single-row roller bearing mounted in the intermediate web. Location and axial thrust are catered for by a combination of a single-row roller journal bearing and a ball bearing, with floating outer and duplex inner races, in an arrangement similar to that for the first motion shaft. The bearing assembly is carried in a housing inserted in the end wall of



Since the box comprises two approximately symmetrical parts and is divided on the plane of the axes of the mainshaft and layshaft, the gears can be fully assembled before they are mounted in position in it



ARRANGEMENT OF THE DAVID BROWN S550 GEARBOX

Careful attention to practical detail is a noteworthy feature of this gearbox as can be seen, for instance, from a study of the scrap view showing the speedometer drive

the gearbox and covered by a cap secured by studs and nuts.

It has not been necessary to incorporate a spigot bearing to support the first-motion pinion. This is because adequate support to the forward end of the mainshaft is given by the intermediate bearing. Advantages of this arrangement are that it reduces costs, improves reliability, contributes to silence in operation and facilitates assembly.

All gears and pinions on the mainshaft, being in constant mesh with the layshaft gears, are carried on wide double-row caged roller bearings. The rollers run directly in the pinion bores, but the inner races are formed by hardened steel sleeves on the shaft. A nut at each end of the shaft retains the whole asembly. In the overdrive top-gear version of the box, because of dimensional limitations, the 19-tooth fourth-speed pinion on the mainshaft is carried by two rows of $\frac{1}{8}$ in diameter needle rollers, the rows of rollers being separated by a steel ring. To avoid unnecessary duplication of components, this arrangement is also used on the fourth speed gear on the direct top-speed gearbox.

The layshaft gears, with the exception of the integral 15-tooth first-speed pinion already mentioned, are separate components pressed on to the shaft and driven by long keys. They are secured by a single nut and locking washer at the front end of the shaft, and their positions are governed by distance sleeves.

An interesting feature of the unit is the inter-relationship between design and assembly. Since the box comprises two approximately equal and symmetrical parts, divided in the plane of the axes of the two shafts, one half of the box forms the container of the entire mechanical and operative assembly, while the other serves as a cover. Also, since the intermediate, front and rear bearings are clamped between the two main castings, the gear shafts can be fully assembled before they are mounted in position.

To assemble the box, the procedure is as follows. The reverse shaft, with its integral gear cluster, is placed approximately in position, but tilted so that the smaller pinion can be passed out through the end of the casing, by way of the bearing housing aperture. From this position it is then brought back, until its front end, on which are mounted the inner race and rollers, enters the outer race, this having previously been assembled into its housing in the intermediate web. This bearing is not clamped, as are those of the mainshaft and layshaft, but is pressed in; movement in one direction is prevented by a lip on the outer race, and in the other by a circlip. Also fitted at this preliminary stage are the gear selector forks, rods and interlock device.

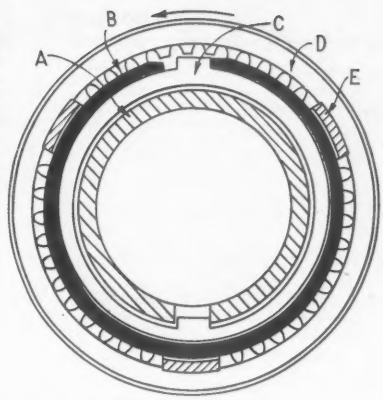
Once these components are in position, the fully assembled layshaft, with its bearings and bearing housings, can be dropped in. The bearing housings, of course, seat in the machined recesses in the lower half of the box. Similarly the mainshaft and the first-motion shaft, complete with bearings and housings, can be lowered into place. Before the box is closed by fitting the top half of the case, the correct positioning of all gears can be checked. Accessibility of the assembly for this operation could scarcely be better. Minor adjustments to the axial position of the assemblies can be made by shimming the end covers; the fit of the outer races of the intermediate bearings in their housings is such as to allow for creep due to expansion.

So far, this description has been devoted to the basic construction of the S550 gearbox. As has been already mentioned, it is distinguished from its forerunners by the incorporation of synchronizing units of the Porsche type. Features of this device are that it is robustly constructed, and has a considerable measure of self-servo action and therefore does not require much manual effort on the gear lever.

The mechanism embodies five essential components, all of which are machined from forgings or stampings: it has

Diagram of a cross section of a synchronizer assembly

A *the driving member, which is pressed on to the gear to be synchronized;* **B** *split ring of spring steel, forming the synchro-cone;* **C** *carrier ring;* **D** *internally-toothed sliding sleeve;* **E** *three-armed spider splined to the mainshaft*



neither light-section pressed steel components nor coil springs. Mounted on the gear or pinion that is to be synchronized is a driving member with small dog teeth round its periphery; the ends of the teeth adjacent to the synchronizer sleeve are chamfered to facilitate engagement. This driving member is pressed on to a register, or spigot, round which are shallow serrations capable of transmitting the drive torque from one component to the other. After the driving member has been fitted, the ends of the serrations are peened to retain it. At the engagement ends of the dog teeth, and on a pitch circle approximately equal to their root diameter, an undercut is machined round the inner vertical face of the driving member to form a shallow conical seating cup.

Two annular steps, or shoulders, are machined round the central boss of the driving member. The larger diameter shoulder carries a split spring-steel synchronizer-ring loosely centralized by the cup formed under the overhanging ends of the dog teeth. This ring is of eccentrically tapered section, as viewed along its axis, the thickest part being diametrically opposite the gap, so that it is not unlike a once common form of piston ring. Its outer periphery is ground to a double-conical, or barrel, shape.

Surrounded by the split ring is a support ring carried on the smaller diameter shoulder on the driving member. On the support ring there is an internal radial lug that registers in a slot in the driving member, and also an external radial lug 180 deg from the internal lug. The external lug projects into the gap between the ends of the split synchronizer-ring, this gap being about $1\frac{1}{2}$ times the width of the lug. A circlip in a groove round the smaller diameter shoulder on the driving member retains both the support ring and the split ring.

The output member of the assembly is a three-armed spider, the hub of which is splined to the mainshaft. At the end of each arm, a fore-and-aft extension, that is, parallel to the axis of the shaft, forms a T-head to carry the clutch sleeve, which is internally toothed in the usual manner to engage the dogs on the driving member. Teeth are machined off to make the slots in which the T-heads of the spider register. Axial movement of the sleeve is effected by a conventional type of gear changing fork. The crests of the internal dog teeth are machined to give the ring a double-conical bore to match the peripheral contour of the split synchronizer-ring.

When the sleeve is moved towards the dog teeth of the driving member, its internal teeth begin to ride on to the synchronizer ring and to push it into light engagement with the conical undercut of the dogs. Since the sliding sleeve is connected to, and therefore rotating with, the output shaft, it then tends to rotate the split synchronizer-ring also. This causes one of the ends of the split ring to abut against the

Gear Ratios

Gear	Box with direct top	Box with overspeed top
Top	1·00 : 1	0·80 : 1
Fourth	1·59 : 1	1·00 : 1
Third	2·76 : 1	1·83 : 1
Second	4·86 : 1	3·38 : 1
First	7·81 : 1	6·28 : 1
Reverse	8·03 : 1	6·44 : 1

Gear Data for the Direct Top-Gear Unit

	Number of teeth			
	Main-shaft	Lay-shaft	Type	Material
First-motion (constant mesh)	19	42	helical, synchro.	En 36 (case hardened)
4th speed	26	36	,, ,,	,,
3rd speed	35	28	,, ,,	,,
2nd speed	44	20	,, ,,	,,
1st speed	53	15	,, dog	,,
Reverse	46/20	19/30	straight dog	,,

external lug on the support ring, which rotates a degree or so in the same direction, until the clearance between its internal lug and the slot in the driving member is taken up. Then the torque tends to expand the split ring, bringing together the conical faces of the friction clutch with greater force, until synchronization is effected. When relative rotation ceases, there is no longer any force exerted between the split ring and the external lug of the support ring, so further movement towards the selected gear position easily compresses the split ring, and the sleeve rides over it into full engagement with the dog teeth.

The self-energizing servo action of the split synchronizer ring greatly reduces both the manual effort of gear changing and the time needed for the operation. Also there is no risk of over-riding the synchronizing elements, as there is when the fixed resistance of a spring-loaded locking device has to be overcome. On the contrary, the greater the force applied through the gear lever the greater is the contact pressure between the cone faces, so crash engagement of the dogs is positively prevented.

To return to the general construction, evidence of the careful attention to practical detail, which is typical of the entire design, is to be seen in the speedometer drive. This is a double-reduction gear arrangement with a spiral-gear take-off from the main output shaft of the box. Ball bearings carry the spindle of the spiral pinion. On this spindle there is also a spur gear, heat treated to 55-65 ton/in², that meshes with a corresponding bronze pinion on the cable coupling spindle. Alternative pinions are available so that the cable speed can be varied to accommodate a wide range of axle ratios or tyre sizes. The design provides for easy access and is an important feature on a proprietary gearbox for such a large range of widely differing chassis. Another interesting feature of the arrangement is that the spiral pinion is twice the length that is necessary for engagement with its gear, only one half being in mesh. After wear has occurred the pinion can be removed and replaced in such a manner that it meshes at its other end to give a second lease of life.

Pipe Joints

The Use of Thermoplastics Pipes Simplifies Jointing Arrangements

In recent years, the development of corrosion-resistant pipes of thermoplastics has greatly simplified jointing methods. When these pipes are used, a paintbrush or blending iron can be employed, instead of a stock and die or welding torch, to make the joints.

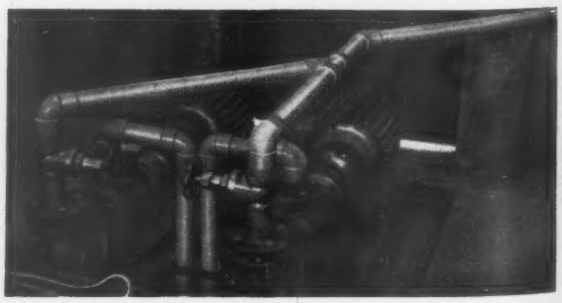
A range of pipes and fittings are currently manufactured, under the registered name of Durapipe, by Richard E. Dupont Ltd., of 56, Kingsway, London, W.C.2. These components are accurately made and are designed specifically for jointing by brush application of either a solvent or an adhesive cement. After the jointing compound has been applied to the end of the pipe and on the inside of the fitting, the pipe is inserted and turned once or twice to consolidate the junction. If the pipes are of large size, they are driven home. The jointing method is so simple that the time required for the installation of industrial pipework systems is much less than when the more conventional methods are used.

Pipes and fittings of another material, termed Durapipe Z, are also being produced by the same manufacturer. This material is of the polythene type, which has a waxy surface that does not easily take adhesives and will not dissolve in any of the common solvents. Dr. Röttner of the German Hoechst Chemical Co., who manufacture Ziegler polythene, discovered that if the oxydized surface is removed, polythene adheres to polythene. As a result, a simple and effective jointing technique has been evolved.

The surfaces to be joined are heated to melting point; then the oxidized layers are removed and the surfaces blended together. This process can be effected by the use of a blending iron, which is a simple tool to manufacture on a lathe. It is an iron of circular section, preferably of bronze or stainless steel, with a counterbore in one end to fit over the pipe and a plug at the other for insertion into the joint. The jet of a blowlamp is directed on to the head of the blending iron, which has previously been marked with a temperature-indicating crayon. When the crayon mark changes colour from blue to white, the tool is at the jointing temperature of 600 deg C. The ends of the components to be joined are heated for ten seconds and then pressed together. This latter operation removes the layer of oxide from the surfaces to be joined, so that they blend together perfectly. The name Durablend is used to describe joints thus made.

Durapipe fittings are also available with standard B.S.21 or A.P.I. threads. If Durapipe has to be coupled to a metal fitting, it may be of advantage to use a gunmetal, compression type joint; particulars of this can be obtained from Lovell and Hanson Ltd., of 312 Spon Lane, West Bromwich.

Durapipe in a factory of The Crittall Manufacturing Co. Ltd.



FUELS AND LUBRICANTS

(CONTINUED FROM PAGE 112)

Part II: Choice of Lubricants to Suit Design and Operating Conditions

C. G. TRESIDDER

VEHICLE operators have always been keenly interested in engine oil developments that lead to operational economy. Over the years, notable changes have taken place; many of these originated in the United States of America. These developments are summarized in Table I. Prior to the introduction of solvent-refined oils, about 1934, the principal method of improving quality was to treat the products with sulphuric acid, and this was followed by caustic washing and clay filtration. Oils of this early type are still available as intermediate quality products. Solvent-treating and de-waxing were introduced to provide oils with improved stability, less viscosity change with temperature and better low-temperature properties than had previously been available, except on a restricted basis, from the conventional refining of carefully selected crude oils. It is also of interest to recall that in 1934, 10W and 20W winter oils were first proposed to the Society of Automotive Engineers, but were not officially recognized until 1950.

In 1935, the inclusion of specially chosen and developed chemicals for improving oil performance first came into widespread commercial use, principally to deal with hard-alloy crankshaft bearing failures due to oxy-acid attack. Later, the newly developed Caterpillar diesel engine, intended for trouble-free operation using low quality fuels, was handicapped by piston deposits; and, in 1938, materials commonly known as dispersive-detergent additives were introduced into engine oil to deal with this problem. These two developments, namely the use of anti-oxidant and detergent additives, opened up a new era of engine oil improvement, which is still in progress.

In 1941, the United States Army accepted the commercial engine oil developments and, in their original specifications 2-104, included five engine test qualification procedures and acceptance requirements designated by the Co-ordinating Research Council as L1, L2, L3, L4 and L5. Now, these engine tests have been reduced to the L1 procedure for detergency and the L4 procedure for oxidation stability. Two pistons from engines that have been subjected to the L1 test are illustrated in Fig. 12. To assist engine oil users, the American Petroleum Institute established in 1945 three oil type classifications. Straight mineral oils were given the designation Regular, while oils containing oxidation inhibitors only and those with inhibitors plus detergent additives were designated Premium and Heavy-Duty respectively.

In 1948, increasing recognition of the influence of fuel sulphur oxides on engines led to the specification of two new

TABLE I: Engine Oil Developments, 1934-1956

Period	Developments
1934–1936	Solvent treatment—improved stability and viscosity index. S.A.E.10W and 20W oils first suggested for easier cold starting. Corrosion inhibitors for sensitive hard-alloy bearings
1938	Detergent type oils for Caterpillar diesel engines
1941	U.S. Army Specification 2-104
1945	A.P.I. designations: "Regular," "Premium," "Heavy-Duty"
1948	U.S. Army Specification 2-104B, Supplement I and Caterpillar Series 2 oils for combating high sulphur fuels (diesel). Increasing attention to minimizing corrosive wear (spark ignition engines)
1949	Up-grading of top quality oils for better control over engine deposits
1950	U.S. Army Specification MIL-O-2104 replaced Specification 2-104B
1951	S.A.E. 5W oils for arctic cold starting
1952	S.A.E. 5W-20 oils for arctic cold starting plus improved oil economy. New A.P.I. service designations: ML, MM, MS, DG, DS
1953	S.A.E. 10W-20, 10W-30 oils to aid control over fuel consumption, wear, deposits, spark plug fouling and oil economy
1954	U.S. Army Specification MIL-L2104A replaced Specification MIL-L-2104. British DEF-2101A
1955	Improved Caterpillar Series 2 oils. Improved S.A.E. 10W-30 and other multi-grade oils
1956	Caterpillar Series 3 oils

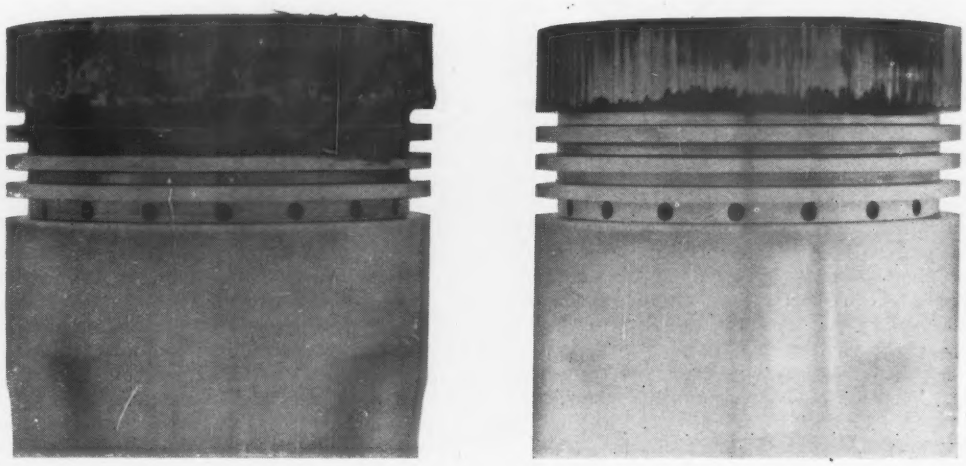


Fig. 12. Pistons that have undergone the Caterpillar 480 hr (L1) test for MIL-L-2104A and DEF-2101A approval. That illustrated on the right has passed the test, whereas that on the left has not done so

Fig. 13. Deposits in camshaft bearing oilways. In the bearing illustrated on the left, oil B was used, while that on the right was lubricated by oil A

performance levels for diesel engine lubricating oils. These were commonly known as Supplement 1 and Supplement 2, the latter being the United States Army equivalent to the Caterpillar Tractor Company Superior Lubricant Series 2 level of performance. In addition, greater attention was given to the reduction, by the use of newly developed additives, of corrosive wear in spark ignition engines under cool-running conditions. In 1949, A.P.I. Heavy-Duty type motor oil first became available, through dealers in the United Kingdom; in later years, the level of dispersive-detergency was increased to assist in combating performance-restricting deposits on engine parts, Fig. 13.

The introduction in 1951 of stable S.A.E. 5W oils to replace kerosine-diluted S.A.E. 10W oils, for arctic cold engine starting, led to unacceptable rates of consumption at high speeds and, commercially, these were replaced in 1952 by oils containing additives to improve the viscosity index. This permitted them to be cross-graded as S.A.E. 5W-20 products, having improved oil economy characteristics, while still retaining the desired low-temperature fluidity. Also, in 1952, the American Petroleum Institute established a revised system of designating engine oils by type of service rather than by type of oil alone. This was the first formal attempt at producing a common guide for oil selection, taking into account critical design and operating factors.

In 1953, the demand in America for passenger cars with engines of increasingly higher compression ratios gave rise to the need for aids in the reduction of knock, pre-ignition, spark plug fouling, cool-running engine deposits and other features that limit performance. This led to the expanded marketing of so-called multi-grade oils of the S.A.E. 10W-30, Fig. 14, and 20W-40 types. In some engine designs, the premature failure of valve train and other heavily loaded parts led to a demand for oils giving additional protection from wear under boundary lubrication conditions; later, this wear problem was resolved mainly by changes in metallurgy.

In 1954, with the introduction of Specification MIL-L-2104A, involving only some minor changes in the physical properties of the oils, the United States Army Specification MIL-O-2104, which superseded Specification 2-104B, became redundant. Also, during this period, the equivalent British Specification DEF-2101A became available. A development in the year 1955 was the change in engine oil test acceptance by the Caterpillar Tractor Co., to assist in overcoming ring sticking in their supercharged engines. This led to the introduction of their classification Superior Lubricant—Series 3 in 1956. In Britain, S.A.E. 10W-30 oils were made more widely available.

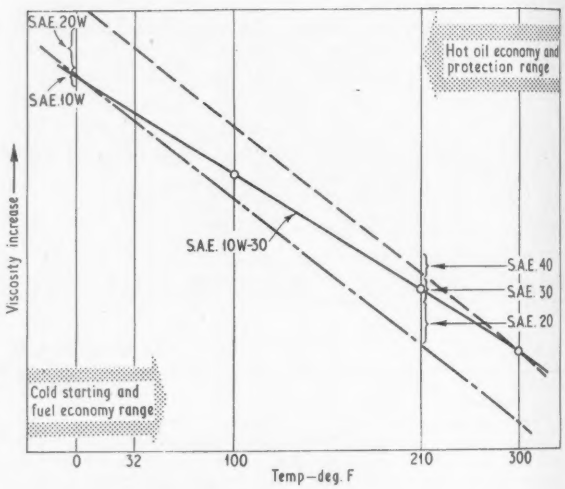


Fig. 14. A typical example of the relationship between the viscosity and the temperature of an S.A.E. 10W-30 lubricant

Modern engine requirements

In addition to reducing friction between moving parts, modern high quality motor oils should have the following chemical, physical and mechanical properties:

1. Oxidation stability, to retard serious deterioration of the oil and to avoid corrosion of hard-alloy bearings
2. Detergency, to help to give better control over varnish, sludge and other carbonaceous deposits that tend to form on engine components at high loads and high operating temperatures. In addition, the detergent quality must be such as to provide also improved protection against sludge and other carbonaceous deposits of the types that occur notably under light-load and low-temperature operation. At the same time, the additives employed should assist in minimizing deposits on valves, sparking plugs, and in combustion chambers and exhaust systems
3. Wear control, especially of cylinders under cool-running conditions and of heavily loaded parts such as the valve train
4. High viscosity-index, to aid cold-starting and, by reducing frictional losses, to give fuel and oil economy at low temperatures and under cool-running conditions. This must be combined with the ability to minimize oil loss due to evaporation and leakage at high operating loads and temperatures

5. Ability to mix readily with motor spirit, for two-stroke engine lubrication.

Uninhibited solvent-refined mineral oils possess good oxidation stability and, generally speaking, are acceptable for engines in which the bulk-oil temperature remains below 200 deg F. Above 200 deg F, the oil oxidation rate doubles for each 18 deg F rise in temperature, and such deterioration can easily lead to undesirable acidity and the formation of oil insoluble carbonaceous materials. However, when solvent-refined oils are fortified with suitable inhibitors, they have a degree of oxidation stability that enables bulk-oil temperatures to be raised to over 250 deg F before serious deterioration occurs. At present, the best method for determining the chemical stability of an oil is by engine test. Several procedures have been developed, none of which is entirely satisfactory when considered alone.

Although detergency occurs naturally, to a varying extent, in all oils, it is only by the addition of complex chemicals that this property can be made significant in automotive engine lubrication and protection. Detergent additives appear to act in two different ways, according to whether the products of fuel and oil deterioration occur at low or high temperatures. In compression ignition engines, particularly of the supercharged type, increased detergency level improves piston cleanliness even when fuel with a relatively large sulphur content is used. With cool-running engines, the substances that form deposits come principally from fuel decomposition. A suitable detergent additive causes some of the deposit-forming ingredients to become soluble in the oil, while the others are held in suspension in a finely divided and harmless form. This lesser-known aspect of detergency, which is of special importance in engines operating under intermittent and start-stop conditions, is of considerable assistance in the control of low-temperature sludge formation. Research studies indicate that, in the absence of detergency at high temperatures, the products of lubricating oil decomposition tend to deposit from the oil, even though highly effective oxidation inhibitors are present. It appears that effective detergents, by arresting important changes that occur during oil decomposition, prevent the formation of lacquer deposits, Fig. 15, particularly on cylinder walls and on pistons.

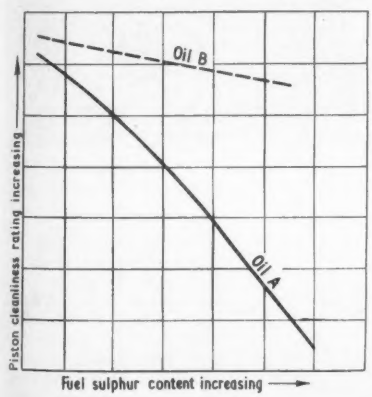


Fig. 15. The effects of detergency level of the lubricant and the sulphur content of the fuel on piston cleanliness obtained in the supercharged CFR diesel engine

Improved detergency enables engine development in the search for increased performance and economy to proceed unhampered. Nevertheless, it is also very important that detergent oils should be compatible with other commercially available lubricants and should not promote trouble in old engines in which considerable deposit accumulations already exist. The effect of detergent oils on existing engine deposits is still a contentious subject, resolved in too many instances by opinion rather than from careful examination of engines in the field. Special test programmes and controlled engineering investigations over the years have failed to establish that detergent oils, even of the most powerful kind in use today, remove existing deposits in such a manner as to cause damage to the engine. Practical experience has demonstrated on many occasions that fleet and individual operators need not adopt troublesome conversion procedures when using detergent oils for the first time.

Illustrated in Fig. 16 are two oil filters taken from the same engine, one after each of two consecutive tests of approximately 8,500 miles duration; a different detergent oil was used for each test. No special conversion procedure was observed in changing from oil A to oil B, but, of course, the filter packs were renewed for observation purposes. Oil B is of markedly higher detergency than oil A. The introduction of detergent oils into engines suffering from ring sticking can lead to a temporary increase in oil consumption, because of the ability of the oil to prevent further resin-like deposit from restricting piston ring action; careful observations have indicated that in such cases, within a few thousand miles, oil consumption returns to and, indeed, often is improved by comparison with that which was previously regarded as normal. There have, of course, been many cases investigated where detergent oil has been blamed for engine failure, but over the last ten years of the author's experience, not one has been substantiated.

Residues from both the fuel and the crankcase oil tend to accumulate in the combustion chamber. In modern spark ignition engine designs, these deposits may glow readily at high temperatures, owing to the amount that accumulates

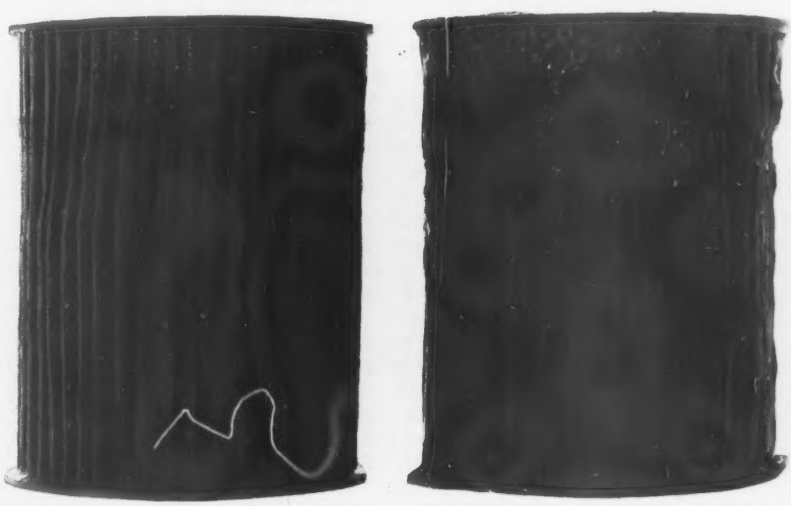


Fig. 16. Oil filters taken from an engine used for field observations. Oil B was used when the filter on the left was fitted, and the heavily sludged filter on the right was removed after oil A had been used

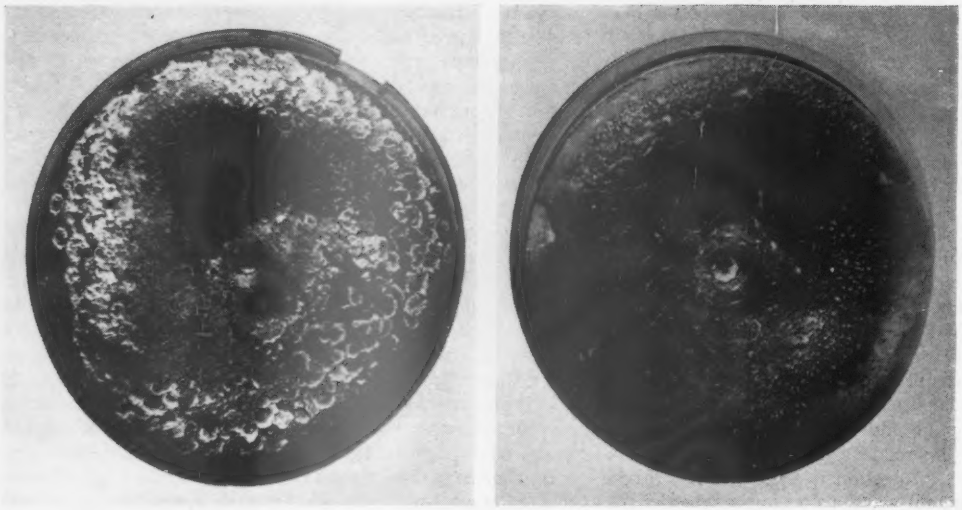


Fig. 17. Deposits on piston crowns: that on the left was obtained in an engine operated with a typical single-viscosity oil, while that on the right was obtained with a new S.A.E. 10W-30 oil

and their scale-like character. This tends to cause undesirable surface ignition and gives rise to an increase in the octane number requirement. In the single-viscosity grades of lubricant the heavy oil component is largely responsible for combustion chamber deposit build-up, and notable improvements have been obtained by the use of S.A.E. 10W-30 oil, Fig. 17.

It is well established that attack on engine parts by the corrosive products of fuel combustion occurs in both compression ignition and spark ignition engines, especially under cool-running conditions. This corrosion leads to accelerated wear, particularly of piston rings, cylinder bores and piston skirts, Fig. 18. Selected additive oils can be used to alleviate this difficulty, Fig. 19.

Lubricating oil is, of course, only one of the many variables that affect engine wear. For several years, urgent consideration has been given to the determination of the influence of oil properties on mechanical wear, especially of heavily loaded valve-train parts. In many instances, these studies are by no means complete, and some have, therefore, led prematurely to misleading conclusions. It is true that some oils are more effective than others in preventing damage due to the scuffing of new components. On the other hand, it seems at present that oils can do little to prevent the pitting of cast iron cams and tappets. Undoubtedly, mechanical wear problems are best tackled by reviewing design geometry and metallurgy, surface finish and production techniques. The introduction of new cast irons offers the greatest promise of benefit in the alleviation of these cam and tappet problems, at least so far as any one measure alone can be expected to help.

The running-in of engines cannot be disassociated from wear considerations. It has been suggested that oils that provide useful protection against wear can be expected to delay the bedding-in of piston rings, a problem which seems to be of special significance when some chromium-plated rings are used. Experience suggests that it is important not only to specify optimum shapes and surface finishes, but also to avoid excessively long periods of operation at low road-speeds during the running-in process. After the first 100 miles or so, engines in most instances can be operated at normal road speeds and loads.

It has been established, and is now widely accepted, that satisfactory S.A.E. 10W oils promoting easy starting from cold, afford useful savings in fuel at the expense only of some increase in oil consumption, by comparison with heavier single-viscosity grades, Figs. 20 and 21. Good quality S.A.E. 10W-30 lubricants fulfil a long-standing need in Britain for products to give optimum results so far as fuel and

Fig. 18. A piston corroded in a cool-running engine operated with an oil of straight mineral type

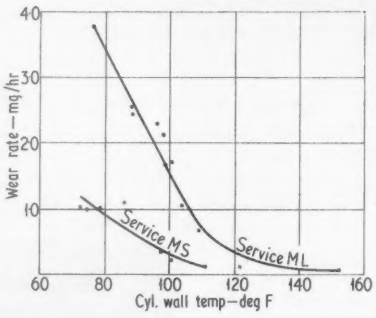


Fig. 19. Effect of cylinder wall temperature on piston ring wear. A straight mineral oil was used for the service ML tests and an additive oil was employed under the service MS operating conditions

oil economy are concerned, a demand which is of particular importance in relation to passenger car operation. The measurement of fuel and oil consumption for the purpose of product comparison in the field is by no means easy. However, under a variety of operating conditions, worthwhile individual fuel economies from as low as 1 per cent to as high as 27 per cent have been established with S.A.E. 10W-30 oil by comparison with S.A.E. 30 oil.

Viscosities and A.P.I. definitions

Many years ago, the automotive and petroleum industries in the United States of America recognized the need for a system by which engine oils could be classified on the basis of viscosity alone. To satisfy this need, the well known S.A.E. Crankcase Oil Viscosity Classification System was introduced in 1926, and it has since been revised a number of

times. Today, S.A.E. viscosity numbers are in common use in Britain and form a valuable guide for oil selection to meet various design and service requirements. But the S.A.E. system has definite limitations, since it does not take account of the many other oil properties.

Just before the last world war, developments in the design of both spark ignition and compression ignition engines, and the service conditions under which they operated, resulted in the introduction of new types of engine oil. These types were employed during the war and were characterized by United States Army Specification 2-104B. To facilitate selection, the American Petroleum Institute was requested to define the oils then in use. This resulted in the A.P.I. designations Regular, Premium and Heavy-Duty, and their definitions were published in 1947.

Service classification

At a later stage, many engine manufacturers and oil companies recognized that the existing A.P.I. definitions also had limitations and, while satisfactory in 1947, did not provide for many new developments in engines and in lubricating oils. Arising from a joint effort by the industries concerned, a new system of Engine Service Classifications for Internal Combustion Engines, with letter designations for the various services, was arrived at to form an improved guide to the selection of oils, the S.A.E. Viscosity System not being affected in any way.

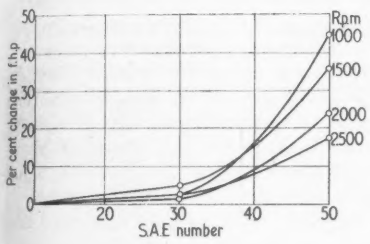


Fig. 20. S.A.E. viscosity plotted against lost horse power of a six-cylinder engine

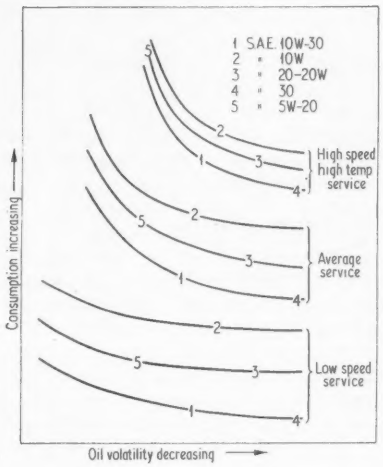


Fig. 21. Oil consumption plotted against lubricant properties and the engine operating conditions

The revised basis of oil selection by engine service classification gave acknowledgement to the fact that the satisfactory performance and service life of internal combustion engines depends in the main on the combination of engine design, construction, fuel quality, operating conditions, maintenance practices and lubricating oil properties. Significant variations in design and construction occur because manufacturers place emphasis on different engine features. Fuels, especially those for compression ignition engines, may also vary markedly, according to the crude oil processed and the refining methods used. Operating conditions include frequent and prolonged idling, light or intermittent load, extreme overloading, and driving varies from low or moderate speeds to sustained high-speed operation. In some countries atmospheric temperatures may range from arctic cold to tropical heat. It is these many factors, separately or in combination, that fix the lubrication requirements of engines.

Engine oil performance and protection properties depend not only on the refining processes, but also on the inclusion of special ingredients during manufacture. For example, some oils are suitable only for light-duty service, while others cover a very wide range of demands; consequently, there are marked variations in initial cost. Even though the engine design is good, operating conditions are easy and the best fuels and lubricating oils are used, inadequate maintenance will, in the end, lead to unsatisfactory results. Investigations and experience in the United States have revealed that for the formulation of an acceptable guide for the selection of automotive lubricating oils, it is necessary to start by combining the principal variables into broad classes of service needs, to cover all ground operating internal combustion engines. As indicated by the A.P.I. service classifications that follow, there is no completely reliable substitute for engine oil evaluation programmes, a few examples of which are outlined in Table III.

Service ML: Service typical of gasoline and other spark ignition engines used under light and favourable operating conditions, the engines having no special lubrication requirements and no design characteristics sensitive to deposit formation

Service MM: Service typical of gasoline and other spark ignition engines used under moderate to severe operating conditions, but presenting problems of deposit or bearing corrosion control when crankcase oil temperatures are high

Service MS: Service typical of gasoline and other spark ignition engines used under unfavourable or severe types

TABLE II: Viscosity Values for Crankcase Oils

S.A.E. viscosity number	Saybolt Universal, sec				Kinematic, C/S				Redwood No. 1, sec			
	0 deg F		210 deg F		0 deg F		210 deg F		0 deg F		210 deg F	
	min	max	min	max	min	max	min	max	min	max	min	max
5W‡	—	4,000	—	—	—	869	—	—	—	3,500	—	—
10W	6,000*	Less than 12,000	—	—	1,303	2,606	—	—	5,250	10,500	—	—
20W	12,000†	48,000	—	—	2,606	10,423	—	—	10,500	42,000	—	—
20	—	—	45	Less than 58	—	—	5·73	9·62	—	—	40·9	51·6
30	—	—	58	Less than 70	—	—	9·62	12·94	—	—	51·6	61·9
40	—	—	70	Less than 85	—	—	12·94	16·77	—	—	61·9	75·2
50	—	—	85	110	—	—	16·77	22·68	—	—	75·2	97·5

**Minimum viscosity at 0 deg F can be waived provided viscosity at 210 deg F is not below 40 sec, Saybolt Universal*
†Minimum viscosity at 0 deg F can be waived provided viscosity at 210 deg F is not below 45 sec, Saybolt Universal
‡The viscosity of oils included in this classification for use in crankcases shall not be less than 39 sec at 210 deg F Saybolt Universal

TABLE III: Examples of Field Test Programmes

Purpose of Test	Number	Type	Total mileage or time
(1) Evaluate effects of fuels and lubricants on combustion-chamber deposits and octane-number requirement increase	36	Passenger cars	200,000 m
(2) Evaluate effects of lubricant types on engine deposits and wear	41	Passenger cars	820,000 m
	25	Light trucks	257,000 m
	36	Tractor-trailer	86,000 hr
	8	Diesel engines	28,000 hr
(3) Evaluate effects of special additives and oils on engine wear, deposits and consumption	68	Passengers cars	665,000 m
(4) Evaluate effects of fuel sulphur and lubricants on engine deposits and wear	56	Passenger cars	1,206,000 m
	7	Diesel earth movers	43,000 hr
(5) Evaluate effects of fuels and lubricants on engine deposits and wear	27	Diesel buses	769,000 m
	1	Tractor-trailer	84,000 m
(6) Evaluate effects of high additive lubricants on clean and dirty engines	24	Passenger cars	265,000 m
	19	Light trucks	200,000 m
(7) Evaluate effects of lubricant types on hydraulic valve-lifter sticking	20	Passenger cars	210,000 m
(8) Evaluate effects of oil drain periods on engine deposits and wear	48	Passenger cars	565,000 m

TABLE IV: Examples of Used Oil Analyses

	New oil	Used oil sample after 3,000 miles city bus service	Used oil sample after 3,000 miles cross country bus service
Flash point, deg F	430	415	420
Viscosity, at 210 deg F, SUS	64	58	65
Estimated fuel dilution, per cent	0	4	trace
Insolubles in pentane, wt, per cent	0	2·1	0·7
Insolubles in benzene, wt, per cent	0	1·9	0·6
Ash, wt, per cent	0·65	0·85	0·72
In ash, spectrographically	additives	major: additives minor: iron, aluminium trace: silicon	major: additives minor: iron trace: silicon
Water	0	trace	0

of operating conditions and where, owing to operating conditions or to engine design or fuel characteristics, there are special lubrication requirements for the control of deposit formation, wear or bearing corrosion

Service DG: Service typical of diesel engines in any operation where there are no severe requirements for control of wear or deposit formation due to fuel, lubricating oil or to engine design characteristics

Service DM: Service typical of diesel engines operating under severe conditions, or where the fuel used is of a type that normally tends to promote deposits and wear but there are design characteristics or operating conditions that may make the engine either less sensitive to fuel effects or more sensitive to residues from lubricating oil

Service DS: Service typical of diesel engines either operating under very severe conditions or having design characteristics or using fuel tending to produce excessive wear or deposits.

Oil change practice

When to change oil is a question of considerable importance, especially to operators of large fleets, who carry out their own repair and maintenance programmes. Having selected an oil likely to satisfy engine requirements, the operator must decide when it should be renewed, taking into consideration operating conditions and the standard of repair and maintenance. In rare cases, where the diesel fuel used is of exceptionally high quality and straight mineral oil can be employed successfully, edge-type filter batch-reclamation is economical. However, experience clearly shows that with detergent oils, filtration alone is uneconomic, troublesome and also it leads to a marked reduction in lubrication efficiency.

The operational factors of major importance in Great Britain are the type of service, prevailing engine loads and speeds, driver habits and, occasionally, the influence of adventitious dust and dirt. Table IV gives analyses of two used-oils, each of which was of the same high quality

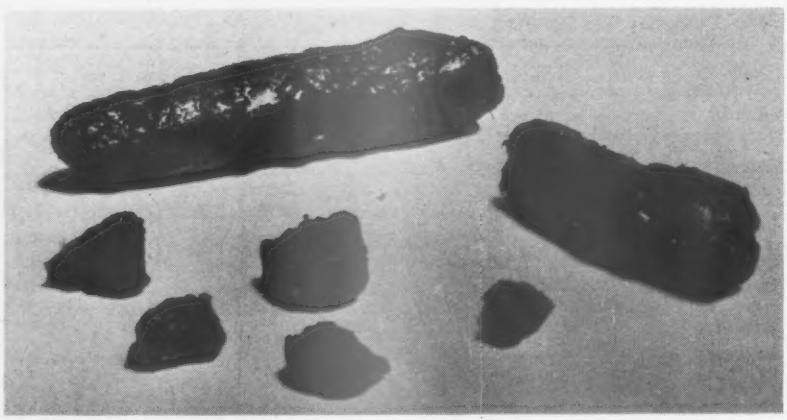


Fig. 22. Baked sludge removed from an oilway of a failed main journal bearing

TABLE V: S.A.E. Gear Oil Classifications

S.A.E. viscosity number	Saybolt Universal, sec				Kinematic, C/S				Redwood No. 1, sec			
	0 deg F		210 deg F		0 deg F		210 deg F		0 deg F		210 deg F	
	min	max	min	max	min	max	min	max	min	max	min	max
75	—	15,000	—	—	—	3,257	—	—	—	13,100	—	—
80	15,000*	100,000	—	—	3,257	21,716	—	—	13,100	87,600	—	—
90	—	—	75	120†	—	—	14·24	25·0	—	—	66·4	106·7
140	—	—	120	200	—	—	25·0	42·7	—	—	106·7	179·2
250	—	—	200	—	—	—	42·7	—	—	—	179·2	—

**The minimum viscosity at 0 deg F may be waived if the viscosity is not less than 48 sec, Saybolt Universal, at 210 deg F*
†The maximum viscosity at 210 deg F may be waived if the viscosity is not greater than 750,000 sec, Saybolt Universal, at 0 deg F, extrapolated

and was employed in the same design of engine using fuel of the same quality, the principal difference being the type of operating condition. It can be seen that in city bus service, contamination with fuel and the products of fuel combustion are significantly higher than in cross-country bus service; this has to be taken into account when deciding upon the lengths of the periods between crankcase oil drainage for the vehicles of the fleet.

Engine service involving a great deal of idling, especially in short-journey winter operation, promotes corrosive wear and low-temperature deposits of sludge. If this is followed by high-speed long-distance service under summer conditions, the physical nature of the sludge changes, causing it to crack and peel and become easily dislodged so that it tends to choke oilways, Fig. 22; in such circumstances, detergent oils have been blamed incorrectly for causing stoppages which were principally due to neglect. Incorrect adjustment to give a rich mixture in spark ignition engines or wrong use of the excess fuel device in compression ignition engines can seriously aggravate crankcase deposit formation.

Operation in a dusty atmosphere may cause abnormal engine oil thickening and, if the dust is abrasive, considerable wear. Influences of this kind are specially significant where air cleaner design or maintenance is faulty, or the protection for crankcase breathing is inadequate. One of the repair practices that adversely affects piston lubrication is that of reclaiming used pistons, for further service, by cutting one or more grooves in the top land and fitting additional rings. The depth and clearance of the top land in relation to the cylinder bore are important factors with regard to piston life and freedom from ring sticking. It is suggested that the only way in which the many variables can properly be taken into account to determine the optimum period between oil changes is by a programme of engine inspection supplemented, as required, by laboratory analyses of correctly taken samples of used and unused oil.

Gear oils and fluids

Not many years ago, any dark-coloured, heavy, viscous oil was considered to be a good lubricant for gears; and the inclusion of additives, such as ground cork and cedar saw-dust was not unknown as a means of assisting in the reduction of noise and the prevention of oil leakage. Today, the situation is, indeed, different. High quality automotive gear-lubricants have been developed: they consist of carefully chosen base oils, often containing several complex additives that impart enhanced properties such as controlled friction, anti-rust, anti-foam, and anti-oxidant protection against wear under both high-speed and high-torque conditions.

As in the case of engine oils, S.A.E. gear oil classifications state viscosity limits only. These are shown in Table V. The lubricants not only vary in viscosity but also contain different additives to suit particular service requirements. In driving axles and transmissions, gears of varying design perform under different service conditions. In some gear sets, tooth pressures and speeds are low enough to permit satisfactory lubrication with straight mineral oils, while the same sets used under more severe load and temperature conditions may require a straight mineral oil that has been reinforced with powerful anti-oxidation and anti-foam ingredients.

Over a number of years, so-called extreme pressure gear lubricants have been developed for automotive spiral bevel and hypoid bevel axles. With these gears, there is a strong tendency for tooth deterioration to occur at high speeds or high torques, or under both conditions, Fig. 23. Some gear sets of these types may function satisfactorily with lubricants that are often described as having mild extreme pressure properties. However, the situation has now been simplified to a considerable extent by the availability of multi-purpose gear oils, which not only have excellent load-carrying capacity to suit high-speed and high-torque requirements, but are also satisfactory for use in worm drive axles where the oil temperature does not rise above 200 deg F. Lubricants of this type are also suitable for use in transmissions of conventional design.

Some of the earlier lubricants for hypoid gears lacked stability at high temperatures of operation and gave little or no protection against rust or corrosion in service. In addition, many were lacking in adequate load-carrying ability under high-torque conditions and proved to be unsatisfactory in shock load tests. Multi-purpose gear lubricants that satisfy the requirements of the U.S. Army Specification MIL-L-2105, for oils acceptable for hypoid gear protection without leading to corrosion and other difficulties, are suitable for many applications. Some hypoid oils not qualified against MIL-L-2105 have been known to protect hypoid gears adequately only in specific designs, and have caused considerable trouble when used in other gear sets for which they were not developed. Various tests are used to determine the performance of an automotive multi-purpose gear lubricant, and research into improved products is very active. Fig. 24 illustrates diagrammatically the performance relationship between existing products, some of which are still available commercially.

For automatic transmissions comprising a combination of a fluid coupling or torque converter and trains of epicyclic gears, the lubricant in many instances is also the power-transmitting medium. In this type of application it is necessary to employ oils of very light viscosity, unusual chemical stability and resistance to foaming in service. Fluids developed specially for automatic transmissions include many containing a wide variety of chemical ingredients to prevent the formation of lacquer and other deposits on the sensitive control mechanisms and, at the same time, to minimize noise during gear changes and to avoid adverse effects on oil seals. To obtain both light viscosity at low temperatures of operation and relatively high viscosity at the high temperatures, which may rise to over 300 deg F, specially selected base oils are used and formulation is closely

Fig. 23. With hypoid and spiral bevel gears, there is a strong tendency for tooth deterioration to occur at high speeds or high torques. These two illustrations show a hypoid gear pair, the teeth of which have failed as a result of inadequate lubrication

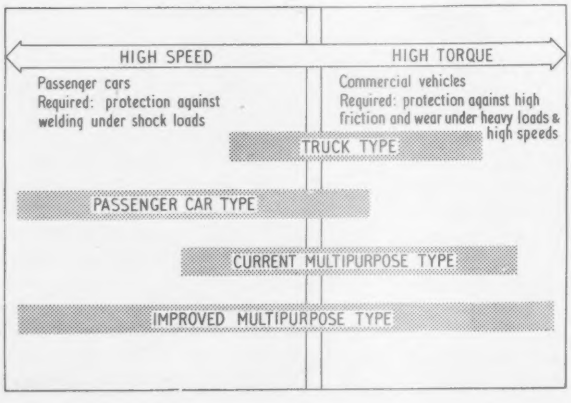
controlled. These measures are essential if the product is to satisfy the rigorous performance requirements demanded for qualification granted under the Armour Institute of America. In many applications only those fluids qualified under the symbol AQ-ATF, by the Armour Institute, are satisfactory for this type of service.

Greases

For many years, the conventional lime, aluminium, soda and mixed-base greases have given satisfactory service when used selectively in automotive applications in Britain. However, there has always been the need to simplify grease lubrication by using one product for the widest possible number of applications. The desired simplification has now been achieved and some excellent multi-purpose greases are available to give improved performance, not only in wheel hub service, but also to afford greater protection against corrosion and wear of chassis fittings.

In some instances, S.A.E.140 gear oil is employed for chassis lubrication because, in the past, greases were too stiff to pump and distribute, especially to tight bushes. Top quality multi-purpose greases combine very good physical and chemical stability at elevated temperatures with soft and easily worked consistencies at low temperatures, so overcoming the many annoying difficulties with dispensing-equipment.

Fig. 24. Types of hypoid gear oil and performance comparisons



In recent years, the performance requirements of wheel hub greases have increased in severity. It is important to emphasize that greases differing in soap type should not be mixed if significant changes in properties are to be avoided in service. Field experiences over the last few years have demonstrated the importance of cleanliness and care when packing grease into wheel hub bearings. If nipples are fitted, there is a tendency to over-filling, with consequent damage to seals. Modern practice suggests that high quality multi-purpose greases can remain in wheel hub bearings for greatly extended service periods, even under heavy-duty conditions.

The author wishes to thank the Chairman and Directors of Mobil Oil Co. Ltd., for their permission to present this paper and also his many colleagues who have assisted in its preparation.

Bibliography

P. H. SCHWEITZER: "Must Diesel Engines Smoke," S.A.E. Meeting, January, 1947.

J. W. LANE and D. S. CHATFIELD: "Effect of Lubricating Oil Viscosity on Engine Performance," S.A.E. Meeting, June, 1949.

G. H. S. SNYDER, E. A. MARTIN, L. RAYMOND and J. F. SOCOLOFSKY: "A Broad Look at Engine-Oil Testing," A.P.I. Meeting, May, 1953.

L. RAYMOND and J. F. SOKOLOFSKY: "Designing New Performance into a Special Motor Oil," S.A.E. Symposium, June, 1954.

J W. LANE and L. RAYMOND: "Automotive Lubricants and Equipment Needs," S.A.E. Meeting, October, 1955.

A. T. WILFORD: "Maintenance of Road Transport Engines with Particular Reference to Smoke Emission," Diesel Engineers' and Users' Association, March, 1956.

C. G. TRESIDDER: "Detergent Action and Engine Cleanliness," *Mobil Automotive Memorandum No.* 1026.

"Automatic Transmission Lubrication," *Mobil Automotive Engineering Memorandum No.* 1011*A*.

"Engine Sludges," *Mobil Automotive Engineering Memorandum No.* 1024*A*.

"Road Diesel Smoke Considerations," *Mobil Automotive Engineering Memorandum No.* 1029.

Foreign Publications

Brief Reviews of Current Technical Books

Kraftfahrzeug-Bremstechnik (Automobile Brake Testing Techniques) VDI Berichte, Vol. 17.

In German.
Düsseldorf: VDI-VERLAG G.M.B.H. 1957. $11\frac{3}{4} \times 8\frac{1}{4}$. 64 pp. Price DM. 11.10.

The Publications Subsidiary of the Society of German Engineers (V.D.I.) issues at intervals volumes containing papers, together with the discussions, presented at specialized conventions. These volumes mainly contain papers that are too long for inclusion in the Society's journal, the *VDI-Zeitschrift*.

In the volume under review, there are five papers that were presented at a Brake Test Convention in 1953. Four of these papers have already been published in extended form, as research monographs in the series *Deutsche Kraftfahrtforschung und Strassenverkehrstechnik*. Three of them are by Prof. O. Bode of Hanover: they deal with test methods for automobile and trailer brakes, a new method of brake testing, and brake test equipment. The two papers by G. Fritzsche and H. Merz are on brake test requirements and brake test results, respectively. All the extended reports are covered by the research monographs Numbers 87, 89, 96 and 97. Of these, Numbers 87 and 89 were reviewed in the July, 1956, issue of *Automobile Engineer*. Therefore, only the papers by Fritzsche and Merz will be dealt with now.

Pages 29 to 33 of the volume contain the paper by Fritzsche, in which the direct and indirect test methods are discussed briefly. Direct measurement has been used in Belgium, Holland and the United States of America, the retardation or brake force at the wheels being measured. With the indirect method, as used in France, Italy, Austria and Switzerland, the mean retardation is determined from the initial speed of the vehicle and the distance over which the brakes are applied. The author gives the main particulars stipulated by the above-mentioned countries and summarizes these in tabular form. Attention is drawn to some of the shortcomings at present met with the direct determinations. However, these are of a rather secondary nature and can be readily eliminated by the use of suitable recording instruments.

Merz, in the paper dealt with in pages 35 to 64, discusses the results of numerous tests carried out mainly along the lines suggested by Prof. O. Bode. The brakes are fully applied as quickly as possible, but the maximum pedal pressure is limited by the provision of a special stop incorporated in the test equipment. Thus, the brake effectiveness is determined as a function of the actuating force at the pedal. These tests are carried out at a number of pedal pressure values. With the equipment developed at Hanover, it is possible to make a comprehensive record of the vehicle braking characteristics, and this, in turn, enables a reliable evaluation to be made of the main factors likely to affect the braking distance. The author considers the theoretical aspects of brake action, the effect of adhesion on braking distance and limiting retardation values for prime mover vehicles, trailers and multi-vehicle trains fitted with air, hydraulic, or inertia-operated brakes. The paper concludes with suggested brake performance data. This whole volume, containing a wealth of information of direct use to designers and testing establishments alike, can be highly recommended to all interested in this vital subject.

Internationale Vergleichsversuche an Abblendlichtern von Automobilscheinwerfen des Amerikanischen und Europäischen Typs (International Comparative Tests on Dimmed Headlamps of American and European Types).

In German. By August Kazenmaier, Dipl.-Ing.
Düsseldorf: VDI-VERLAG G.M.B.H. 1956. $8\frac{1}{4} \times 11\frac{3}{4}$. 26 pp. Price DM. 12.80.

Originally the series of monographs published by the German Society of Engineers (V.D.I.), under the heading of "German Powered Vehicle Research," dealt with the results of researches sponsored by the German Ministry of Transport. However, it became apparent that its scope should be enlarged to embrace also research work carried out independently by universities, technical highschools and industry, since the results of these investigations are in many instances of fundamental as well as of topical value, but their availability to engineers is generally limited. Therefore, the scope of the V.D.I. monographs has now been enlarged to include reports on this research, and the title of the series has been altered accordingly to "German Power Vehicle (Motor Car) Research and Road Traffic Engineering."

The monograph under review is No. 94 of the series and, as pointed out by the author, was originated because after the war the conflicting practices with regard to headlamp arrangements on cars of Continental origin on one hand, and American and British origin on the other, lead to complaints. Continental drivers claimed to suffer from the dazzling effect of headlamps of American cars, even though they were dipped. A request to study the relevant problems was made by the United Nations to the Commission Internationale de l'Eclairage (C.I.E.). As a result of several meetings, a working panel was formed in 1951. This panel was later known as the Groupe de Travail Bruxelles 1952, and it included representatives of the United Kingdom, America, Belgium, France, Germany, Italy, Holland and Switzerland. German representatives carried out kinetic tests on curves on dry roads, as well as on wet and straight roads, with headlamps adjusted in the normal manner. The results of these tests form the subject of the monograph.

Details of the tests, with two vehicles fitted alternately with headlamps of Continental and American origin and running towards each other at a steady speed of about 40 m.p.h., are discussed. The headlamps and their adjustment are considered, and the results of the various tests are presented in considerable detail by the use of curves and tables. A brief conclusion and recommendations abstracted from the complete report of the Brussels panel terminates the work. These recommendations were put forward in Detroit in 1954. They are to the effect that each system has its advantages and disadvantages, and because of this, it was not possible to come to a unanimous agreement as to which should be accepted universally as the standard dimmed-lamp arrangement. The final report was approved by the C.I.E. Congress in 1955 and passed to the United Nations authorities in Geneva.

While this monograph represents an interesting and valuable addition to the limited literature dealing with this subject, it covers only one aspect of the comprehensive tests carried out by the representatives of the countries forming the working panel. The publication of the results of the complete tests should provide further valuable data relating to the increasingly important subject of headlamp performance.

Konstruirovanie, Issledovania, Ispitania Avtomobilei (Design, Investigation and Testing of Automobiles).

In Russian. Edited by V. D. Maiboroda.
Moscow: STATE PUBLISHING HOUSE FOR ENGINE BUILDING LITERATURE. 1956. $8\frac{5}{8} \times 5\frac{3}{4}$. 100 pp. Price 3 roub. 50 kop. (3s.).

Published in conjunction with *Avtomobilnaia i Traktornaia Promishlenost*, this volume is the second of a series that includes papers of topical interest, which have not appeared in that journal. The first article, by Chanin and Chistosvonov, deals with six-cylinder V-type engines, this layout being attractive to Soviet vehicle designers on the score of overall length reduction. These authors concentrate on the more important aspects of crankshaft dynamics and general analysis of the parameters of existing engines of this type. They conclude that, in terms of space-saving, an engine of the 90 deg V-layout is to be preferred, although vibrational considerations limit its use to heavier lorries. With lighter vehicles, preference should be given to 60 deg V-engines.

Snaking of four-wheel trailers is considered in an article by Osepchugov. The author deals with the results of tests carried out on nine trailers, the payload capacities of which were between 2 and 6 tonnes. Measures that should be taken to alleviate excessive snaking were discussed. Next, Knoros, Klennikov and Stefanovitch deal with the lateral forces on the front wheels of motor cars, with particular reference to reducing tyre wear during cornering. Some of the conclusions are substantiated by test results.

A method of calculating the length of a flame jet in compressed air is put forward by Lishevsky. The author concludes that, over a time interval of 0·002-0·005 sec, and at air pressures of 5-30 atm, the proposed method is in satisfactory agreement with experimental evidence. Design of roller type differentials, with particular reference to front axle drives, is dealt with by Prosvirin and Irhin. Reference to test results suggests that Soviet designers are seriously considering the adoption of this design for production vehicles. Degtiarev reports on tests carried out to determine the amount of dust rejected through

exhaust pipes after its passage through engine cylinders. It is of interest to note that, in general, only some 17·5 per cent of the dust that passes through the air cleaner into the engine finds its way out through the exhaust.

The causes of stiction and resultant torsional vibrations of automobile couplings are considered, by Kosterin and Kragelski, against the background of theories put forward by Bowden and Leben on one hand, and Ushlinski and Kragelski on the other. Some preliminary test data are presented to illustrate these problems. Uspenski deals at length with some aspects of the calculations for the design of torsion bars of circular and rectangular cross section, while Gureev and Sablina consider the effect of anti-detonants on the chemical stability of petrol fuels for cars. After an article by Lvov, on the use of condensers for spark suppression at voltage regulators, the book concludes with another, by Isaev, on the effects of pipe-line distortion on the fuel supply of compression ignition engines.

Most of the papers are of a high standard and the variety of the topics dealt with in this small volume vividly recalls Goethe's words *"Wer vieles bringt wird manchem etwas bringen."* This paper-bound book is well produced, copiously illustrated, and its price is modest.

Uber Verbrennungstoren und Kraftfahrwesen (About Internal Combustion and Motor Car Matters).

In German. By Prof. Alfred Jante.
Berlin: V.E.B. VERLAG TECHNIK. 1956. 8¼ × 6. 624 pp. Price D.M. 18.10.

This volume contains numerous papers previously published by the staff of the Institute for Internal Combustion Engine and Automobile Research, of the Technical Highschool of Dresden, which is headed by the distinguished engineer and teacher, Professor Jante. The work of this Institute is dealt with at the annual convention held at Dresden and the papers are subsequently published in East German technical journals, notably *Die Technik* and *Kraftfahrzeugtechnik*. However, since the papers are of a fundamental character, most of them have been republished in book form, and the volume under review is the third edition of this valuable collection.

In it, the first section, comprising 340 pages, is devoted to engines; the second section contains 165 pages, dealing with vehicles; and the third consists of 116 pages on agricultural tractors. Since the problem of part-load fuel consumption is one of the most important with which modern engine designers and vehicle builders are faced, considerable space is devoted to it, notably in the papers by Prof. Jante. These papers occupy about half of the book. The first deals in a clear and concise manner with the fundamentals of engine cycles, as viewed from a practical angle. This is followed by a paper on part-load performance of engines based on the ideal Seiliger cycle. Other papers by Jante give an appraisal of different engines, in terms of vehicle requirements, and deal with the trend of engine development. These occupy about 100 pages, and are of the type that can be read and re-read with considerable pleasure and profit. They are singularly clear and deal in a most thorough and stimulating manner with important aspects of engine performance.

Next, the fundamentals of supercharging are considered by Hinze, and this is followed by a paper by Richter dealing with the results of tests on multi-disc piston rings evolved by Wolf. The tests were carried out in an Adler-Trumpf-Junior car. Another paper by Richter discusses cylinder and piston wear. This is followed by two papers by Prof. Jante: one is on some design parameters of American diesel engines, while the other is on the performance of the Ricardo-Pintaux nozzle. In other sections, Nowak deals with the development and performance of the I.F.A. standard fuel injection pump, and Meissner with the flow characteristics of a concentric nozzle. A comparison between a Stendel four-cylinder radial engine and units of more conventional design is made by Hofmann, while Jante deals with the development of diesel engines for ships.

The next section of the book, pages 222-340, is devoted to petrol engines. Here, Jante considers the possibilities of reducing part-load fuel consumption. This discussion is based on numerous tests carried out by the Institute. The theory and practice of carburettor investigations, partly with reference to engine fuel consumption, are dealt with in 59 pages by Hinze and Freche. The next paper deals with a method of detonation limit determination, based on the fact that, during detonation, heat dissipation from the combustion space to the cylinder walls is appreciably increased. It was considered that, *inter alia*, detonation could be indicated by the sudden temperature rise; the tests to verify this assumption are dealt with in some detail. Tests carried out in connection with the development of combustion chambers for the I.F.A. F.9 engine are dealt with by Hoffmann. The first part of the book is concluded with a paper, by Künzelmann and Richter, on tests with a gas generator using vaporized diesel fuel or oil, or a mixture of both.

Vehicle performance is dealt with in the second part. In this section there are a number of papers by Prof. Jante. They discuss the effect of speed, braking, etc., on the distance between vehicles; skidding, based on tests made by the staff of the Road Research Laboratory; the effect of engine characteristics on vehicle performance; the graphical determination of vehicle performance; the development of vehicles, as affected by the fundamentals of traction mechanics; the effect of driving habits on fuel consumption; and the fundamentals of vehicle aerodynamics. The subjects are dealt with in a clear and lucid manner, and the work is of the high standard that we have come to expect from this author.

While most of these subjects also appear in the author's book "The Mechanics of Power-Driven Vehicles," reviewed in the February, 1956, issue of *Automobile Engineer*, some additional facts of interest to automobile engineers are also presented. In addition, this part of the book contains the results of vehicle performance tests carried out by Prof. Jante and members of the staff at the Institute. These include work done with the UMW.340, 2-litre car, the I.F.A. F.9 0·9-litre car, the I.F.A. F.8 car powered by a two-stroke, two-cylinder, 0·7-litre engine, the improved F.9 car and the Horch type H3A 6-litre lorry. The tests are on the overall performance, transmission efficiency, tractive resistance, and suitability of the gear ratios of these vehicles. Particular attention has been devoted to the part-load fuel consumption. The presentation and evaluation of the test data is a model of what information of this type can and should be. This section concludes with Prof. Jante's observations on the 1954 Paris Motor Show, and some notes on the value of racing as a means of fostering vehicle development.

The final part, which is on tractors, includes contributions by Prof. Jante on power and performance requirements, as well as suggestions for a rotary ploughing machine, and its performance and layout as affected by gear ratios. Air cleaning and the design and performance of air cleaners are dealt with, by Richter, on the basis of test results. This author also considers the layout and performance of large-area, air cleaners mounted on the roof, as suggested by Hilbert. He also considers the theoretical and practical aspects of the performance of the cyclone type pre-cleaner, the theoretical considerations being mainly based on previous work by Prof. Feifel, of Vienna. The book concludes with a paper by Richter on the performance of oil filters.

A brief review of the subject matter of this volume can scarcely be expected to do full justice to such thorough and thought-provoking papers. The work has contributed materially to the clarification of problems relating in particular to the interaction between vehicles and their engines, and especially to the overall vehicle performance in terms of fuel consumption. This latter subject seems to be of particular interest to Prof. Jante. It is fortunate that this is so, for while many engineers and research workers have concentrated on the development of transmissions and suspension, the reduction of part-load fuel consumption has not always received the attention it merits. On this score alone, this interesting and useful book should be a welcome addition to the libraries of design and development engineers, motor car manufacturers and research institutes.

BOOKS for AUTOMOBILE ENGINEERS

AUTOMOBILE CHASSIS DESIGN
By R. Dean-Averns. 2nd Ed. 30s. net. By post 31s. 0d.

AUTOMOBILE EFFICIENCY
Maintaining Performance with Electrical Test Equipment. By E. T. Lawson Helme, A.M.A.E.T., A.M.I.M.I. 10s. 6d. net. By post 11s. 1d.

GAS TURBINES AND JET PROPULSION
By G. Geoffrey Smith, M.B.E., Revised by F. C. Sheffield. 6th Ed. 35s. net. By post 36s. 6d.

THE MODERN DIESEL
Automotive Oil Engines for Transport, Marine and Industrial Use. By Donald H. Smith, M.I.Mech.E. 12th Ed. 12s. 6d. net. By post 13s. 6d.

THE MOTOR VEHICLE
By K. Newton, M.C., B.Sc., A.C.G.I., A.M.Inst.C.E., M.E.Mech.E., and W. Steeds, O.B.E., B.Sc., A.C.G.I., M.I.Mech.E. 5th Ed. 35s. net. By post 36s. 6d.

Obtainable at all booksellers or from
ILIFFE & SONS LTD
DORSET HOUSE, STAMFORD ST., LONDON, S.E.1

THE FUESS METAL SPECTROSCOPE

A New Visual Instrument for Routine Production Control

R. H. Tyas, A.Met., L.I.M.*

A HIGH standard of control is essential in the manufacture and assembly of the multitudinous number of components that comprise the modern motor vehicle. The need for the rapid sorting and grading of metals and alloys is becoming increasingly evident and a new visual spectroscope, manufactured by R. Fuess of Berlin-Steglitz, appears capable of satisfying this requirement. The equipment, shown in Fig. 1, and also Figs. 4 and 5, consists of the following items:

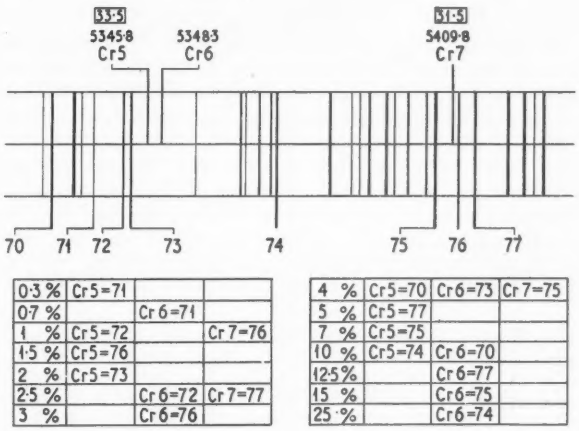
1. A high dispersion spectroscope of very compact design.
2. Sample tables enabling the spectrum of an unknown sample to be compared directly with that of a known standard sample.
3. A photometer attachment allowing measurement of the relative intensities of selected spectrum lines.
4. Guide rods for the optical alignment of the equipment.
5. An adjustable resistance for current regulation.
6. A source unit providing an intermittent A.C. arc between the sample and a disc electrode of copper or iron.

Instruction manuals giving details of the operation and adjustment of the equipment, analytical techniques, charts of line pairs and calibration graphs are also supplied.

When an electric arc is struck between two metal electrodes light is emitted. The radiations of which the light is composed are characteristic of the elements that are present in the electrodes. A spectroscope sorts these radiations and presents them to the viewer as spectrum lines, each positioned in order of wavelength. The presence of a spectrum line of definite wavelength indicates the presence of a certain element and it is therefore possible to identify the major and minor constituents of an alloy.

The sample is arced against a counter electrode of copper or iron and the spectrum examined visually by means of the spectroscope. Selection of a particular spectrum line is made by means of a drum calibrated in arbitrary units, conversion of these units to wavelength being made on a standard graph. Only during development of a particular procedure is such a conversion necessary, since during routine analysis a line is selected merely by setting the measuring drum to the appropriate value stated in the manual. As shown in Fig. 2, the chromium 5 line is selected by setting the measuring drum to 33·5.

The comparison sample table greatly facilitates the operation of the instrument by producing adjacent to the



0·3 %	Cr5=71		
0·7 %		Cr6=71	
1 %	Cr5=72		Cr7=76
1·5 %	Cr5=76		
2 %	Cr5=73		
2·5 %		Cr6=72	Cr7=77
3 %		Cr6=76	

4 %	Cr5=70	Cr6=73	Cr7=75
5 %	Cr5=77		
7 %	Cr5=75		
10 %	Cr5=74	Cr6=70	
12·5 %		Cr6=77	
15 %		Cr6=75	
25 %		Cr6=74	

Fig. 2. Extract from the illustrations of the spectrum in the manual

The comparison sample table greatly facilitates the operation of the instrument by producing adjacent to the

British Iron & Steel Research Association, Sheffield Laboratories.

Fig. 1. General view of the Fuess metal spectroscope set up with its accessory equipment. From right to left: spectroscope, second specimen table, photometer, first specimen table, adjustable resistance, and arc generator

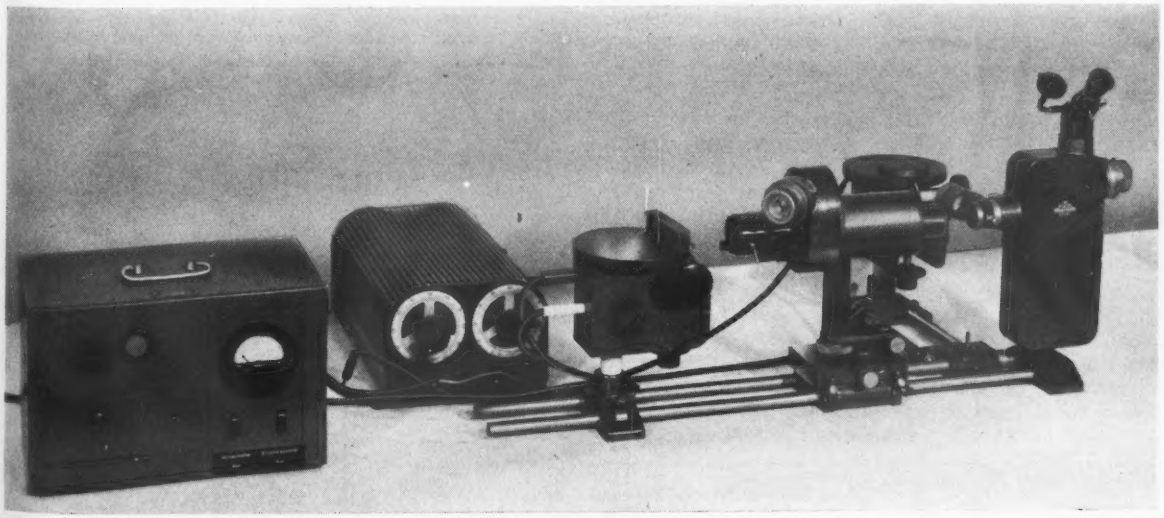


TABLE I—Range of concentrations covered by the photometer attachment

Element	Concentration Range, per cent		
	Steels	Cast iron	Al-alloys
Co	2 —50	—	—
Cr	0·03—34	0·03—1·2	—
Cu	0·1 — 3	0·1 —3	0·2 — 5·5
Fe	—	—	0·15— 3
Mg	—	0·03—0·2	0·16—12
Mn	0·1 — 6	0·1 —2·2	0·10— 2
Mo	0·05—15	—	—
Ni	1·4 —36	—	—
Ti	0·08— 1	—	0·25— 3
V	0·15— 8	—	—
W	1 —28	—	—
Zn	—	—	0·15— 3

unknown spectrum, a second spectrum of the element or alloy to be identified. A satisfactory procedure is to arc on the comparison table a sample of the base material containing no impurities or alloying elements, while at the same time arcing on the analysis table the sample under investigation. The lines of the base element are present in both spectra, whereas the lines of the impurities or alloying elements appear only in the analysis spectrum and can, therefore, be recognized immediately. The effectiveness of this procedure in identifying spectrum lines is partly responsible for the ease with which the operator acquires experience.

Qualitative analysis—the identification of metals and alloys

Although the equipment can be used without the photometer attachment, only in certain restricted applications is this procedure recommended. In this event a chart is provided whereby more than fifty elements giving rise to spectrum lines in the visible region of the spectrum can be identified. An adequate supply of materials to provide comparison spectra is essential, however, if positive proof of such identification is to be obtained. For steel, cast iron, copper and aluminium alloys detailed working instructions and graphical illustrations of the spectrum have been provided and all useful element and iron lines have been identified and numbered. When the spectroscope is used without the photometer, an impurity line is compared with a number of nearby lines of the base element and if two selected lines have the same brightness a certain concentration of impurity is indicated. These concentration values, together with the spectrum lines used are presented in the form of tables, an extract from the working instructions being shown in Fig. 2.

Although this method of analysis is accurate when carried out carefully and systematically, it is obviously necessary for the operator to familiarize himself with the lines used and to be able to recognize, immediately, a small group of lines present within a large series. It follows that should an operator be required to carry out semi-quantitative analysis of a wide variety of metals and alloys, his period of training may be unduly long. This disadvantage has in the past restricted the application of visual spectroscopes in Gt. Britain. This is not so in Europe where about one thousand Fuess metal spectroscopes are used in all branches of industry, in many cases without the advantage of the recently developed photometer attachment.

Quantitative analysis—the photometer attachment

The aforementioned disadvantage of the simple spectroscope completely disappears with the use of the photometer attachment. Fig. 3 shows the optical layout of the attachment,

TABLE II—Results of short term reproducibility tests

Per cent	Cr	Mn	V
Chemical Mean	0·34	0·60	0·19
Spectrographic Mean	0·32	0·62	0·19
Range	0·29–0·35	0·55–0·68	0·17–0·22
Standard Deviation*	0·022	0·044	0·017
Coefficient of Variation*	±6·9	±7·1	±8·9
Mean Coefficient of Variation	±7·6		

*The standard deviations and coefficients of variation were calculated as follows:

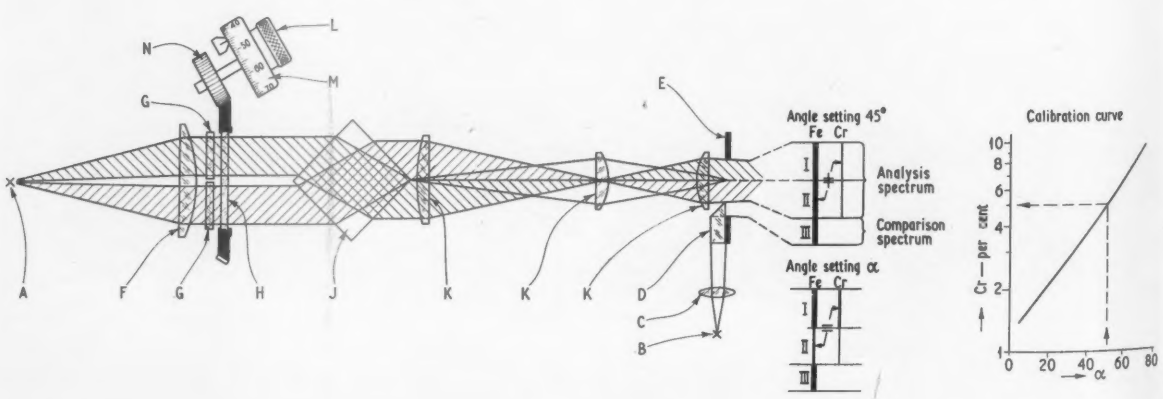
Standard Deviation, S.D. $= \sqrt{\frac{\Sigma d^2}{n-1}}$

Coefficient of Variation, C.V. $= \frac{\text{S.D.}}{C} \times 100$

where d = deviation from the mean
n = number of determinations
C = mean percentage concentration.

illustrating the method of analysis and the form of calibration graph used. Light from the arc is split into two beams, polarized in mutually perpendicular planes, and each giving rise to a spectrum. The calibrated drum of the photometer operates a polarizing filter and when set to an angle of 45 deg,

Fig. 3. Optical layout of the photometer attachment. Diagrams showing the method of spectrum analysis and the form of the calibration graph
A *analysis arc (first specimen table)*; **B** *comparison arc (second specimen table)*; **C** *lens*; **D** *comparison prism*; **E** *slit*; **F** *lens*; **G** *fixed polarizing filters*; **H** *rotatable polarizing filter*; **J** *Huefner rhomb*; **K** *lenses*; **L** *control knob*; **M** *measuring drum*; **N** *pinion drive*



both spectra are of equal intensity. Rotation of the drum then causes the intensity of one spectrum to increase while the other decreases, or vice-versa, according to the direction the drum is rotated. Thus, when the element line is viewed in one half of the spectrum and the comparison line in the other, rotation of the calibrated drum enables the two lines to be adjusted to equal intensity.

The outstanding advantage of this procedure is that a single line-pair can be used over a very wide range of concentration, thus reducing the number of lines to be memorized. Briefly the procedure is as follows:

The spectroscope is set for the required element, the sample is placed on the specimen table and the arc is then switched on. The photometer control is rotated and the two selected lines are adjusted to equal brightness. Up to four readings can be taken in one minute and the determination completed by converting the mean reading to concentration on the appropriate calibration graph. Routine analysis does not require the use of the second sample table. During the initial training period of the operator, however, the second specimen table proves invaluable.

Calibration—accuracy—experience

Twenty-four calibration graphs are supplied with the instrument and other graphs are in preparation. The concentration ranges covered are shown in Table I. The graphs for steel have been found to be accurate and stable and little variation is expected from one instrument to another. The accuracy obtained on aluminium alloys is not as good as that obtained on steels and is probably due to the heating and arcing effect of the sample.

The two most important features of the photometer attachment are the ease with which the operator acquires experience and the accuracy of the results obtained. With the aid of a set of training samples supplied by the manufacturer, operating experience is acquired very rapidly and much useful analysis can be carried out after only one week's experience. This is due to the small number of line pairs to be memorized and the design of the instrument which is both simple and comfortable to operate, thus reducing operator fatigue to a minimum. The latter point is extremely important where visual spectroscopic analysis is to be carried out on a large scale.

Fig. 4. The Fuess metal spectroscope with two specimen tables

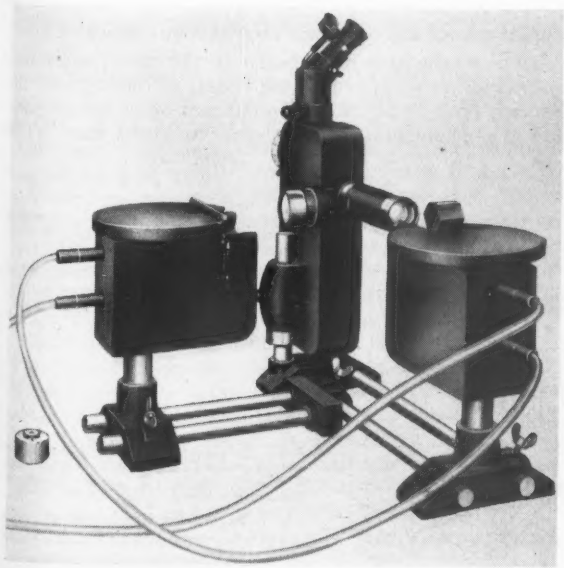


Fig. 5. Photometer attachment for the metal spectroscope

An assessment of the accuracy of the results obtained has been made by the British Iron & Steel Research Association* and a table from their report is shown in Table II. The mean coefficient of variation of 7·6 per cent agrees closely with that obtained by the more thorough tests carried out by the manufacturer. With operational experience acquired so rapidly it is possible to put the instrument into routine operation within one week of installation. Depending on the accuracy required, the speed of analysis varies from 15 to 60 seconds for one element.

Applications

As a means of production control in the automobile industry the Fuess spectroscope has many possibilities. It can be used to control scrap and other materials used in the production of ferrous and non-ferrous alloys. The determination of magnesium in S.G. iron can be completed in one minute, offering closer analytical control in the foundry. A great number of differing materials are used by manufacturers and the sorting and grading of stocks is often required; a task performed most efficiently by the spectroscope. The crater made by the arc during analysis is relatively shallow and can generally be sited on the least important face of the sample. Since the method is non-destructive, the analytical specification of finished products can be ascertained.

The range of heat-resisting alloys at present in use is extremely wide and a specification check, carried out before a component enters service, could prove invaluable. Time and effort can be saved if inspection is carried out on the spectroscope, followed by a minimum of chemical analysis. In certain instances impurity elements or alloying elements of low concentration can be determined with an accuracy comparable with that of routine chemical analysis. Offering rapid and reasonably accurate analysis of a wide range of materials, its application will continue to spread as new line spectra are investigated. Costing approximately one quarter the price of conventional spectrographic equipment it could be operated in industry as a very efficient and useful tool.

The instrument and equipment is supplied by Surfard Ltd., Abbey House, Victoria Street, London, S.W.1.

*Tyas, R. H. "*A New Spectroscope for Visual Analysis*," Metallurgia, June* 1956, *Vol. LIII, No.* 320, *pages* 285-288.

THE PNEUMATIC GOVERNOR

Mode of Operation and Advantages of This System for Application to Compression-Ignition Engines

Dr. Charles R. Webb

MANY compression-ignition engines fitted in modern road vehicles of British manufacture are equipped with pneumatic governors. With this arrangement, the throttle control is connected to a butterfly valve in a venturi through which the inlet manifold is supplied with air, and the depression at the throat of the venturi is used to move the rack of the fuel pump. This arrangement is adopted in preference to connecting the throttle control directly to the rack of the fuel pump, and allowing the engine to breathe entirely freely.

The aim in this paper is at analysing the mode of operation of the governor system, and demonstrating its advantages. Actual performance curves of an engine working with and without a governor are included, both for comparison and to illustrate the analysis.

Equipment

A Perkins P4, four-stroke industrial engine, coupled to a Heenan and Froude hydraulic dynamometer, was used for the tests. It was fitted with a fan, water pump, generator, and a heavy industrial type flywheel. A thermostat was incorporated to control the jacket temperature. The particulars of the engine are: four cylinders, 3·50 in diameter bore, 5·0 in stroke, and 16·5:1 compression ratio, and the static timing of the injection is 29 deg B.T.D.C. (port closure).

In this type of unit, fuel injection is effected by a C.A.V. pump fitted with the C.A.V. pneumatic governor, illustrated in Figs. 1 and 2. The butterfly valve at the throat of the venturi control unit is actuated by the speed control linkage. Rotation of the butterfly valve is limited at one end of its range by the adjustable idling screw, and at the other end by the adjustable maximum speed screw. A small pipe connection to the venturi throat transmits the venturi depression to the diaphragm. For test purposes, a water manometer was connected to this pipe. Also, a scale was fitted to measure the rotation of the butterfly valve in degrees. On this scale, the idling position was represented by zero and the butterfly was fully open after 59 deg of rotation. The maker's setting for the maximum speed stop was at 25 deg.

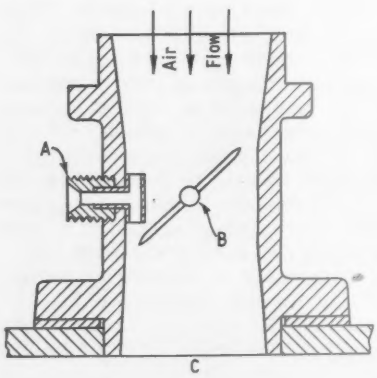
Mounted on the end of the fuel pump is a pressure-tight housing, in which is the diaphragm assembly, the leather diaphragm actuating the pump rack. In the absence of any depression in the diaphragm chamber, a spring moves the rack to rotate the plunger so that the scroll is in the maximum delivery position. The greater the depression, the smaller is the volume of fuel delivered. At idling, an additional spring comes into action, for reasons which will be apparent later. This spring can be adjusted to give satisfactory slow running. When it was required to render the diaphragm control inoperative, the chamber was opened to atmosphere.

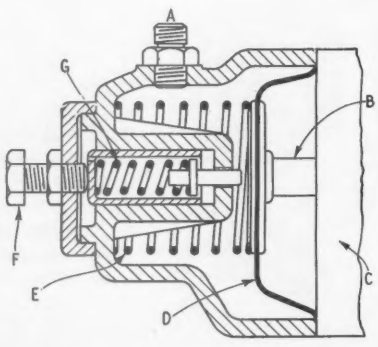
For the tests, a pointer was fitted to one plunger to indicate its degree of rotation under the influence of the depression in the diaphragm chamber. This rotation is, of course, directly proportional to the linear movement of the rack. When the rack was fully open, the pointer read zero on a scale divided in degrees, and when the rack was in the "stop" position, the pointer indicated 46 deg on the scale.

The air supply to the engine was measured by a standard orifice in a large box, and precautions were taken to prevent inaccuracies due to fluctuations in the flow. The fuel used was Shell gas oil, and the consumption was measured with a 100 cm³ burette.

Performance curves of an ungoverned engine

To assess the basic performance of the engine, tests were made with no restriction at the manifold, that is, with the butterfly open 59 deg, the fuel pump rack operated manually, and the diaphragm chamber open to atmosphere. The



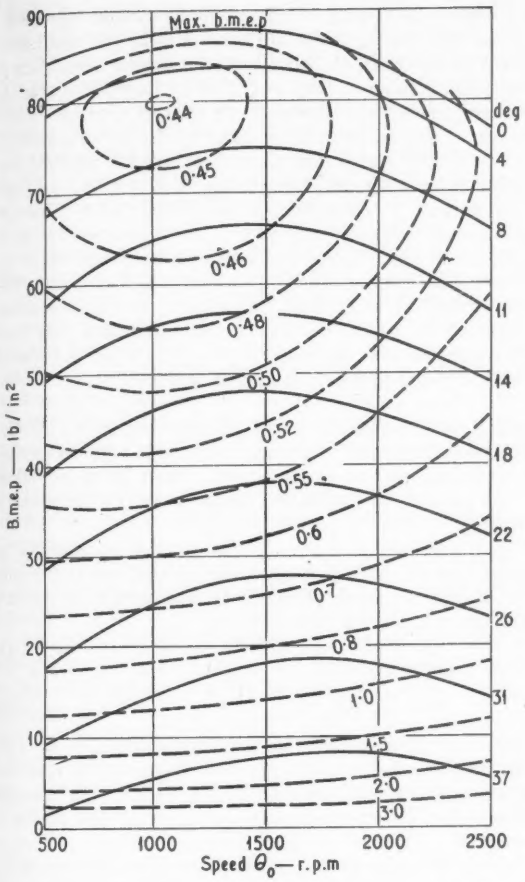


A *the connection for the pipe transmitting depression to the diaphragm;* **B** *butterfly valve;* **C** *inlet manifold*

Fig. 1. Left: The venturi control unit of the C.A.V. pneumatic governor

A *the pipe connection from the venturi control unit;* **B** *rack;* **C** *pump body;* **D** *diaphragm;* **E** *control spring;* **F** *idling adjustment;* **G** *auxiliary spring*

Fig. 2. Right: The diaphragm chamber of the governor unit that is fitted to the C.A.V. fuel injection pump



——— Lines of constant rack-position, expressed as the rotation of the plungers in degrees
– – – Lines of constant specific fuel consumption, expressed in lb/b.h.p-hr

Fig. 3. Engine performance curves obtained without governing

speed was varied from 500 r.p.m. to 2,500 r.p.m., and a number of runs were made at various fixed positions of the rack. Brake mean effective pressure, which, of course, is proportional to torque, is plotted against speed in Fig. 3. This illustration shows how the b.m.e.p. varies with the position of the rack, as indicated by plunger rotation, from the maximum delivery stop position to a delivery little greater than that required for idling.

Air consumption, at N.T.P., plotted against speed is shown in Fig. 4, on which a curve of volumetric efficiency is also given. The consumption is almost proportional to speed over most of the range, the volumetric efficiency falling off slightly at high speeds. Air consumption is dependent solely on engine speed, irrespective of the rack position. Curves of fuel consumption against speed, for the same rack positions as those of Fig. 3, are given in Fig. 5. Within the limits of experimental error, these curves are straight lines; this indicates that the fuel delivered per stroke of the pump is virtually dependent only on the rack position.

The curves of constant specific fuel consumption in Fig. 3 were drawn from the information given in Fig. 5. These curves are a family of loops of the form usually obtained with an internal combustion engine; the centre of the group indicates the conditions under which the engine will run at maximum brake thermal efficiency. The mean value of fuel delivered per stroke of the pump, for various positions of the rack, was computed from Fig. 5. A curve of fuel delivered per stroke against pump plunger rotation is given in Fig. 6.

Performance curves of a governed engine

For the tests with the governor in operation, the pipe connection from the venturi to the diaphragm chamber was refitted. The same measurements as before were taken, but the runs were made at various fixed positions of the butterfly valve control instead of fixed positions of the rack.

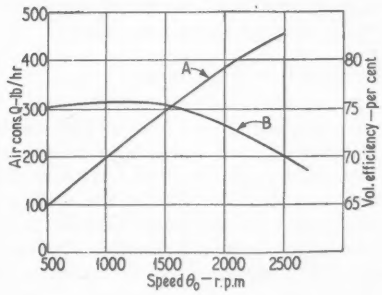
Fig. 7, in which b.m.e.p. is plotted against speed, also shows lines of constant opening of the butterfly valve in degrees. In general, the curves follow a typical pattern: for example, the 20 deg curve gives nearly constant b.m.e.p. from 500 r.p.m. to about 1,500 r.p.m. This is because over this range, the fuel rack is against its stop in the maximum delivery position, the venturi depression being insufficient to overcome the rack spring. Within the limits of experimental error, the curve is identical with the maximum b.m.e.p. curve, of Fig. 3, over the speed range of 500 r.p.m. to 1,500 r.p.m.

At a slightly higher speed, the depression becomes sufficient to reduce slightly the delivery, and at almost 1,700 r.p.m., the b.m.e.p. falls off very rapidly. Towards the end of the rack movement, the curve again shows an increase in speed as the b.m.e.p. is reduced: this is known as the high-speed run-out. The absolute maximum speed at the 20 deg setting of the butterfly valve, is about 2,200 r.p.m., when the engine is unable to produce any appreciable power.

To some extent, the shape of the high-speed run-out portion of the curve is influenced by the effect of the additional spring on the pump rack. Furthermore, it can be seen that as the butterfly valve is opened, the speed at which the b.m.e.p. falls away is increased. At any position of the butterfly valve, below the speed at which the governor rapidly cuts off the fuel the b.m.e.p. follows the maximum curve of Fig. 3.

The curves of Fig. 7 were recorded as the speed increased. With decreasing speed, slightly different readings are obtained, giving a kind of hysteresis effect. This comes about because of friction in the diaphragm unit and pump rack, and with the equipment used, was very slight.

From a control point of view, the arrangement operates as a stable speed-governed system over the nearly vertical



A *air consumption;*
B *volumetric efficiency*

Fig. 4. The relationship between air consumption and the speed of the engine

portion of each curve. At the extreme ends, non-linear effects in the system cause the curves to depart seriously from the vertical, but it will be shown that these effects are not necessarily disadvantageous. The desired speed is set by the butterfly valve, and over the nearly vertical range of each curve of b.m.e.p. plotted against speed, the speed is maintained sensibly constant, irrespective of load on the engine.

Fuel consumption was measured, and the curves of constant specific fuel consumption were superimposed on Fig. 7. These curves follow the same general pattern as those in Fig. 3. It is, therefore, clear that loss of neither power nor efficiency of the engine results from the fitting of the governor control.

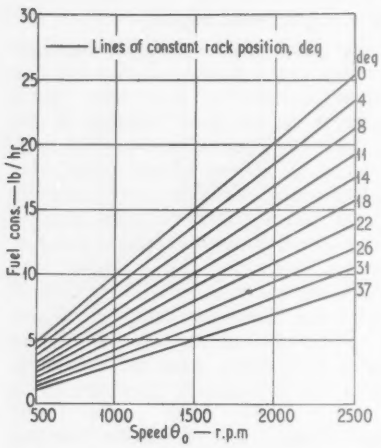


Fig. 5. The relationship between the fuel consumption and the speed of the engine

At all positions of the butterfly valve, the curve of air consumption plotted against speed, with the governor operating, was almost identical with that of Fig. 4. This shows that there is not any loss of volumetric efficiency because of the restriction imposed by the venturi unit. Under all conditions, the amount of depression is insufficient to reduce the air:fuel ratio below that required for correct combustion. Probably the restriction at the engine inlet valves is considerably greater than that at the butterfly valve.

Graphs of air consumption plotted against venturi depression, for various positions of the butterfly valve, are shown in Fig. 8. From this illustration, it can be seen that the depression is directly dependent not on engine speed but on the flow of air induced by the engine. Another curve, Fig. 9, shows the relation between plunger rotation and depression, as read from the manometer. It can be seen that the rack remains fully open until a certain depression is applied, after which the plungers rotate, almost linearly with increasing depression, towards the closed position. At high values of depression, the slope of the curve changes, showing the action of the additional stiffness, which opposes the rack motion. From the information given in Fig. 6, a second curve has been drawn on Fig. 9; this curve shows the fuel delivery per stroke plotted against depression, and it is similar in shape to the other curve.

Governor control loop

It will be shown that over the nearly vertical range of the b.m.e.p-speed characteristics the engine and pneumatic governor together function as an almost linear closed-loop proportional speed-control. A block diagram of the loop is shown in Fig. 10. Briefly, the desired speed θ_1 is a signal determined by the positioning of the butterfly valve and transmitted to the differential. The measured, or controlled, speed θ_0 transmits to the differential a signal determined by the air flow through the venturi. The output of the venturi unit is the depression p. This is proportional to the speed error θ, which is equal to $(\theta_1-\theta_0)$. Thus, the venturi unit combines the functions of differential and proportional controller G_1. The box G_2 represents the fuel pump, which receives the signal p, and provides an output signal in the form of a supply of fuel. This is fed to the engine G_3, which thus is caused to run at speed θ_0. Finally, the speed θ_0 determines the rate of air flow that feeds the differential. External load on the engine is represented by the signal U, which reacts on the engine, denoted here by G_4, and in turn affects the controlled speed θ_0.

This system is subject to two kinds of disturbance: first, changes in desired value of speed θ_1; and second, changes of external load U. The function of the control is to keep the speed error θ at a minimum in the event of load changes, but to enable the system to operate over a range of speeds.

Let us consider first the air flow Q over the restriction imposed by the butterfly valve. The resultant depression p at the throat is likely to vary as Q^2, rather than directly as Q; this characteristic is common to all venturi devices. Confirmation of this relationship is given by the set of curves of Fig. 8. The curve obtained depends on the amount the butterfly valve is opened. From Fig. 9 it can be seen that, for the present purpose, the operating range of p is limited to between 20 in and 23 in of water. Therefore two ordinates are drawn in Fig. 8, one at 20 in and the other at 23 in, and only those portions of the Q-p curves that lie within this limited range are considered. It is clear that the operating portions of the curves are virtually straight, and that their slope increases with the value of θ_1. The relation between changes in p and Q can be written as follows:

$$p=K_1Q \tag{1}$$

where K_1 is a constant for any one set value of θ_1, but decreases as θ_1 increases. In other words, at any one set speed, the controller has an output proportional to speed error, but the gain of the controller decreases as the set speed is increased.

Fig. 4 indicates that the air flow Q can be regarded as proportional to controlled speed θ_0, or since θ_1 is constant at some desired speed, Q varies directly with $-\theta$, where θ is the speed error. Therefore:

$$Q=K_2\theta_0 \quad =-K_2\theta \tag{2}$$

so that, using equation (1):

$$\frac{p}{\theta}=-K_1K_2=G_1 \tag{3}$$

Equation (3) describes the transfer function of the controller G_1, that is, the ratio between changes in output and input signals, as a constant K_1K_2. The negative sign indicates that the controller can make a corrective action, as is required.

We now consider the transfer function of the fuel pump G_2. The movement l of the pump rack is dependent on the following:

- A Effective diaphragm area
- p Depression at the diaphragm chamber
- M Effective mass of the moving parts
- B Equivalent viscous damping coefficient for the moving parts
- K Stiffness of the rack spring

If l is considered to be positive as the rack moves to reduce the fuel delivery, we can equate forces at the rack:

$$Ap=Kl+BDl+MD^2l \tag{4}$$

where D is the differential operator with respect to time $\left(\frac{d}{dt}\right)$, and can be treated, for the purpose of this analysis, as an algebraic quantity. It is evident, from Fig. 5, that the fuel delivery per pump stroke F can be regarded as nearly proportional to rack movement. Therefore:

$$F=-K_3l \tag{5}$$

so that, using (4), and eliminating l:

$$\frac{F}{p}=-\frac{K_3A}{K+BD+MD^2}=G_2 \tag{6}$$

Equation (6) describes the transfer function of the pump G_2, that is, the ratio between changes in output and input signals, as a second order complex transfer lag. This can be conveniently expressed as:

$$G_2=-\frac{\frac{K_3A}{K}}{1+2CTD+T^2D^2} \tag{7}$$

where the numerator is a constant,

$T=\sqrt{\frac{M}{K}}$ is the time constant of the complex lag, and

$C=\frac{B}{2\sqrt{MK}}$ is the damping ratio.

With the installation used for the tests, it was found that if the rack was moved manually and then released, while the diaphragm chamber was subject to a medium depression, the rack executed a damped oscillatory motion and then came to rest. This shows that the damping is less than critical, or in other words, that $C<1$.

The third transfer function G_3 of the engine itself can now be investigated. First consider a hypothetical engine that operates at constant specific fuel consumption, in other words, one that develops power proportional to the rate of fuel consumption. This implies that the developed torque varies directly with the fuel delivered per stroke of the pump. Figs. 3 and 7 show that, over a wide range of torque and speed, the specific consumption does not vary widely. Thus, to a first approximation, we can assume that the torque is proportional to fuel delivered per stroke. At low values of torque, however, this assumption is not valid, and a non-linear condition is introduced; this will be discussed later.

The speed of the engine θ_0 for constant external load, is dependent on the following:

$\mathcal{J}$ Equivalent inertia of the moving parts

B_1 Equivalent viscous damping coefficient of the moving parts

F Fuel delivered per stroke

We can, therefore, equate the changes of input and output torque:

$$K_4F=B_1\theta_0+\mathcal{J}D\theta_0 \qquad (8)$$

where K_4 is a constant relating the developed torque to the fuel delivered per stroke. Equation (8) can be re-arranged to give:

$$\frac{\theta_0}{F}=\frac{K_4}{B_1+\mathcal{J}D}=G_3 \qquad (9)$$

Equation (9) describes the transfer function of the engine G_3, as a first order exponential transfer lag. The equation may be more conveniently expressed as:

$$G_3=\frac{\frac{K_4}{B_1}}{1+T_1D} \qquad (10)$$

where the numerator is a constant, and $T_1=\frac{B_1}{\mathcal{J}}$ is the time constant of the engine lag.

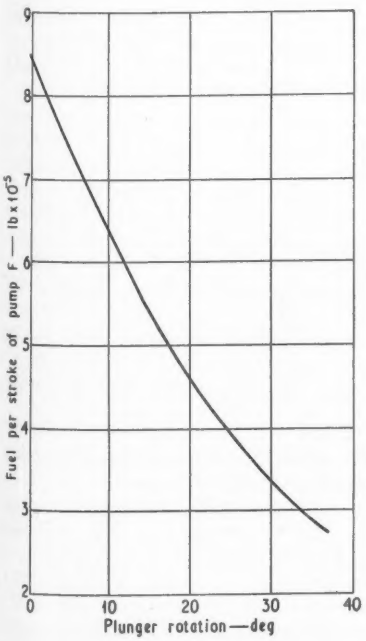
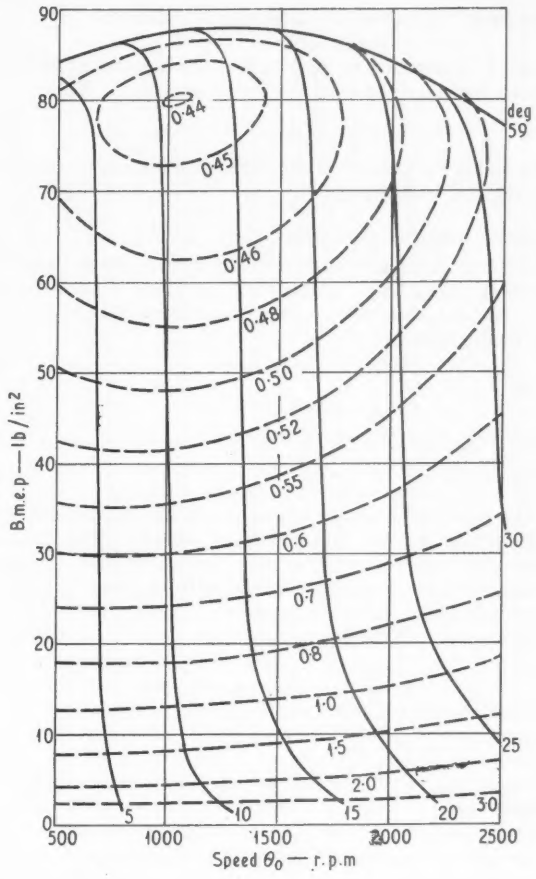


Fig. 6. Curve showing how the quantity of fuel injected per stroke of the pump varies with the setting of the plunger



——— Lines of constant opening of the butterfly valve, expressed in degrees
— — — Lines of constant specific fuel consumption, expressed in lb/b.h.p-hr

Fig. 7. The performance curves obtained with the engine governed

We can multiply together G_1, G_2, and G_3 to the obtain loop transfer function G. Thus, from equations (3), (7), and (10):

$$G=G_1G_2G_3=\frac{pF\theta_0}{\theta pF}=\frac{\theta_0}{\theta}$$

$$=\frac{\frac{K_1K_2K_3K_4A}{KB_1}}{(1+2CTD+T^2D^2)(1+T_1D)}$$

$$\therefore G=\frac{\theta_0}{\theta}=\frac{\mu}{(1+2CTD+T^2D^2)(1+T_1D)} \qquad (11)$$

where $\mu=\frac{K_1K_2K_3K_4A}{KB_1}$ is the proportional control factor.

Equation (11) describes the dimensionless loop transfer function G, connecting the change of output speed θ_0 resulting from any error θ. Also μ is dimensionless and can be regarded as almost constant for any set speed θ_1. However, since K_1 decreases as θ_1 increases, so does μ, which means that the control becomes less sensitive as the speed increases. The denominator of the right-hand side of equation (11) indicates that the loop is a third-order oscillatory system.

For changes in external load torque L, when the set speed θ_1 is fixed, we may consider a load disturbance U as being represented by L/B_1, that is, the torque change per unit of engine damping; it has the same units as the resultant change in θ_0. The transfer function G_4 can now be obtained. By equating load torque change to the friction and inertia

changes of the engine, the following is obtained:

$$-L=B_1\theta_0+\mathcal{J}D\theta_0 \qquad (12)$$

where L is regarded as positive if it tends to decelerate the engine, that is, if the external load is increased. Thus:

$$G_4=\frac{\theta_0}{U}=\frac{-1}{1+T_1D} \qquad (13)$$

Equation (13) describes the dimensionless engine-transfer function for load changes.

System transfer function

It is now desirable to consider the overall system transfer function. For a combination of the two kinds of disturbance, the resultant change in θ_0, from equations (11) and (13), can be expressed as:

$$\theta_0=G\theta+G_4U \qquad (14)$$

Since θ is $(\theta_1-\theta_0)$:

$$\theta_1-\theta=G\theta+G_4U$$

Therefore: $\theta(1+G)=\theta_1-G_4U$

and

$$\theta=\frac{\theta_1}{1+G}-\frac{G_4U}{1+G} \qquad (15)$$

The right-hand side of equation (15) can be split into its two parts to express, first, the speed error resulting from a change of desired speed θ_1 in the absence of load changes, and, second, the speed error resulting from a load change in the absence of a change of set speed.

Of these, the first is given by:

$$\theta=\frac{\theta_1}{1+G} \qquad (16)$$

and the second is given by:

$$\theta=-\frac{G_4U}{1+G} \qquad (17)$$

Substituting for G in equation (16), from equation (11), we obtain:

$$\theta=\frac{\theta_1(1+T_1D)(1+2CTD+T^2D^2)}{[\mu+(1+T_1D)(1+2CTD+T^2D^2)]} \qquad (18)$$

This equation can be solved for various characteristic types of θ_1 disturbance. For a step disturbance in θ_1 of $\hat{\theta}_1$, θ will be a damped oscillation with a final steady-state value of $\frac{\hat{\theta}_1}{\mu+1}$. This can be seen from equation (18), since in the steady-state, all the terms containing D are zero. Note that the steady-state error decreases as μ increases, but it will be shown later that stability requirements limit the increase in μ.

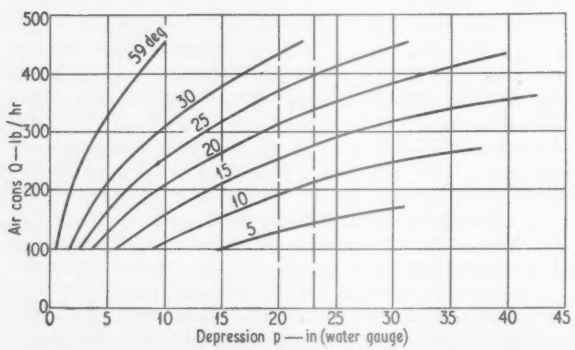
Substituting for G in equation (17), and also for G_4 from equation (13), we obtain:

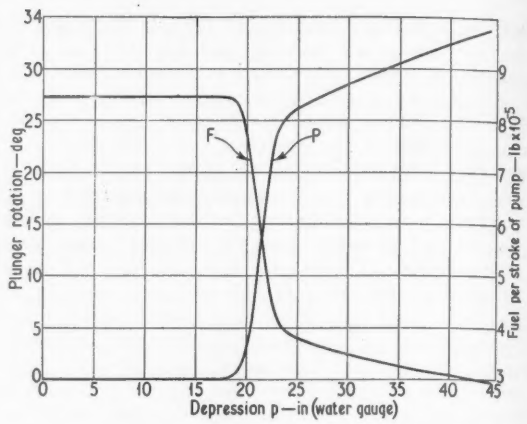
$$\theta=\frac{U(1+2CTD+T^2D^2)}{[\mu+(1+T_1D)(1+2CTD+T^2D^2)]} \qquad (19)$$

For a step load-disturbance of $\hat{U}$, θ will again be a damped oscillation, with a final steady-state value of $\frac{\hat{U}}{\mu+1}$. Note that the steady-state error again decreases with μ.

The frequency of the damped transient response that precedes the steady-state response can be evaluated by solving either equation (18) or equation (19), and this frequency is the natural damped frequency of the system. Solution of these equations is beyond the scope of this paper, and practical tests on the system show that a suitably high frequency, of the order of $\frac{1}{2}$ to 1 cycles per second, is generated.

Fig. 8. The relationship between the air consumption and depression
——— Lines of constant opening of the butterfly valve, expressed in degrees





F fuel delivered per stroke of the pump; P plunger position, in degrees of rotation

Fig. 9. Characteristics of the diaphragm pneumatic governor unit

Stability of the control loop

It is essential that transient oscillations following disturbances should be suitably damped, because in the absence of damping, the oscillation would continue indefinitely, and there would be a complete lack of control over the system. The conditions required for stability, that is, the propagation of damped oscillations, can be determined by applying the Routh-Hurwitz stability criterion. This consists of analysing the coefficients of D in the characteristic equation of the system. The latter is obtained by equating to zero the denominator of either equation (18) or equation (19), to give:

$$0=T^2T_1D^3+(2CTT_1+T^2)D^2+(T_1+2CT)D+(\mu+1) \qquad (20)$$

In general, the characteristic equation can be written as:

$$0=aD^n+bD^{n-1}+cD^{n-2}+dD^{n-3}+eD^{n-4}+fD^{n-5}+\ldots. \qquad (21)$$

From equation (20), the coefficients in this case are:

$a=T^2T_1$
$b=2CTT_1+T^2$
$c=T_1+2CT$
$d=\mu+1$
$e=0$
$f=0$, etc.

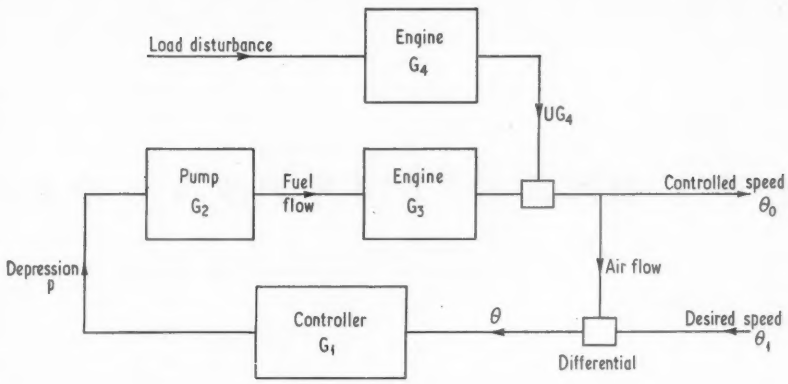
We can now write the array:

a	c	e	g	–	–
b	d	f	h	–	–
$X_1=\frac{bc-ad}{b}$	$X_2=\frac{be-af}{b}$	–	–	–	–
$Y_1=\frac{X_1d-bX_2}{X_1}$	$Y_2=\frac{X_1f-bX_3}{X_1}$	–	–	–	–
–	–	–	–	–	–

This array is complete when the terms become zero horizontally and vertically. In this particular case:

T^2T_1	T_1+2CT	0
$2CTT_1+T^2$	$\mu+1$	0
$T_1+2CT-\frac{T^2T_1(\mu+1)}{2CTT_1+T^2}$	0	0
$\mu+1$	0	0
0	0	0

Fig. 10. Block diagram of the control loop



Stability is obtained provided that the signs of the terms of the first vertical column are identical. This evidently requires that:

$$T_1+2CT>\frac{T^2T_1(\mu+1)}{2CTT_1+T^2}$$

which, when re-arranged, becomes:

$$\mu<\frac{(T_1+2CT)(2CTT_1+T^2)}{T^2T_1}-1 \quad (22)$$

This shows that the proportional control factor μ can only be increased to a limited extent if the system is to remain stable. We have already seen that μ depends on K_1, K_2, K_3, K_4, A, K, and B_1, which are all parameters of the system. All these parameters are sensibly constant, except K_1, which causes μ to become larger as the set speed is reduced. This is confirmed by Fig. 7, which shows that the slope of the b.m.e.p. curves over their nearly vertical range tends to become steeper as the butterfly valve is closed. It is essential to keep μ as high as possible to obtain the greatest possible sensitivity and small steady-state errors. The parameters of the control system have been chosen so that stability is obtained except at very low speeds.

The effect of the additional spring in the fuel pump is now clear. If this spring is made inoperative, the engine does not idle at a uniform speed, but hunts continuously, indicating unstable control. By adjusting the spring so that K is suitably increased at small delivery rates of the fuel plungers, the engine idles under stable control and runs smoothly. To keep the control as sensitive as possible, it is desirable to set the modified value of K so that hunting is only just prevented.

Departures from linearity

In the previous section the nearly linear performance of the speed governors has been discussed, but reference to Fig. 7 shows that the system departs from linearity at each end of the load range. At high loads, as soon as the fuel plungers are rotated to the maximum delivery position, that is, when the rack movement is arrested by the stop, further increase in load can only result in a reduction in speed. Under these conditions, the governor system is said to be saturated, and control is lost.

The departure from linearity at small loads, that is, the high-speed run-out, occurs to some extent as a result of the influence of the additional rack spring. However, the major reason for this departure is that the specific fuel consumption becomes very high at small loads, and reaches infinity at zero load. This is an inherent failing of all internal combustion engines, and the effect on the governing system is to reduce K_4 steadily as the external load becomes very small. This causes a major reduction in μ, and the slope of each curve of b.m.e.p. against speed becomes progressively smaller over this range. In the circumstances, it is difficult to suggest how the high-speed run-out can be avoided without undue complication.

Practical advantages of the governor

Primarily, the object of the governor system is to prevent an engine from over-speeding on light loads, as it might easily do with direct rack control. To obtain a suitable maximum speed irrespective of how much load falls away when the throttle pedal is fully depressed, it is only necessary to set the screw stop on the butterfly valve.

In a vehicle, the most usual condition is for the engine output to balance a uniform medium load at a uniform speed. The speed is determined by the position of the throttle pedal, and is maintained despite large variations in load. The driver in many instances may not be conscious of these load variations. If the throttle pedal is depressed, the vehicle accelerates to a higher uniform speed, which again remains constant despite large changes in load. When the engine is developing maximum torque at any particular speed, further depression of the throttle pedal can make no difference to the engine output, and therefore no acceleration takes place. The driver senses this dead effect and thus is warned that a gear change may become necessary.

Finally, a great improvement in idling is possible by the use of the governor. With direct rack control, the rack can only be set against an idling stop. If the rack is set for slow idling, the slightest increase of load on the engine causes it to stall. With the governor fitted, a slight increase of load reduces the speed momentarily. This in turn causes the air flow to be reduced, and the resultant drop in depression immediately causes the plungers to be rotated to give a greater rate of fuel delivery, so the engine speed increases again. The control is very sensitive at idling, and the response to slight disturbances is sufficiently rapid to prevent the engine from stalling. In other words, a much slower and more stable idling speed can be set.

The author wishes to make acknowledgment for the fact the the engine tests described were made in the laboratories of Queen Mary College, University of London.

M.I.R.A. PUBLICATIONS

Research Reports Released for General Circulation

1955/2 An Investigation of the Cause and Nature of Brake Squeal.

1955/4 The Effect of Carburizing Conditions and Heat Treatment on the Bending Fatigue Strength of Gears Made from an En362 Type Steel.

1955/5 Measurements of Operating Bending Loads in Automobile Engine Crankshafts.

1955/6 Measurements of Operating Torsion Loads in Automobile Engine Crankshafts.

1955/7 Improving the Bending Fatigue Strength of Stub Axles by Shot Peening and Cold Rolling.

1955/8 The Effect of Lead on the Bending Fatigue Strength of Gears made from an "Economy" Carburizing Steel.

1955/9 An Investigation of the Character and Causes of Road Noise in Vehicles.

1956/3 An Investigation into the Mechanism of Oil Loss Past Pistons.

1955/10 A Review of Hydrokinetic Fluid Drives and Their Possibilities for the British Motor Industry.

OPPOSED-PISTON OIL ENGINES

A Brief Survey of Units With Rocker-Actuated Crankshafts

R. WARING-BROWN

THE constant demand for increased space in all classes of motor vehicles poses a paramount problem in the design of a modern chassis, and affects practically every unit in its construction. This demand is particularly pressing in regard to heavy motor vehicles. For long-distance coaches and public service vehicles the call is not only for increased seating capacity, but also for extra space for luggage stowage. Consequently, much attention has been focused on the design of horizontal engines for underfloor installation, and as larger vehicles designed for operation at higher road speeds gradually evolve, more powerful engines are essential. One advantage of the underfloor layout is that it enables a low centre of gravity to be obtained.

Generally, the power plant for this class of vehicle is of the compression ignition type. However, this does not absolutely preclude the petrol engine. Broadly, the engine must develop high horse power per pound of weight, consistent with economic fuel consumption. It must also be of compact design and construction, robust, durable, and easy and economic to maintain.

To meet these essential requirements, engineers have recently been studying departures from the traditional four-stroke type of engine, and have considered the possibilities of units operating on the two-stroke principle. Experience has shown that an improved power:weight ratio can be obtained if the valves of the conventional four-stroke types of design are eliminated.

It appears that a horizontal engine with opposed pistons offers definite advantages for this class of work. A three-cylinder unit of this type can give a power output approximately equivalent to that of a normal six-cylinder, four-stroke engine, while at the same time it satisfies the other basic requirements. Opposed-piston engines with rocker-actuated crankshafts are by no means a new idea. They have been used even in some very early steam engines, and the principle was applied by Ochelhauser to gas engines. Subsequently, the layout was adopted by Hill and Sulzer for oil engines for automotive purposes.

The Hill engine

Fig. 1 shows the Hill design. Two horizontal pistons operate in a single cylinder, above the centre of which is a pre-combustion chamber. The crankshaft is beneath the cylinder, and the connecting rod of each piston actuates a rocker joined by a coupling rod to the crankshaft. This multiplicity of working parts is amply compensated for by the good balance attained. Further, only three cylinders are necessary to give power similar to that developed by an equivalent six-cylinder four-stroke engine of conventional construction.

Nevertheless, there are disadvantages to the layout. In fact, the introduction of rockers and additional connecting links between the opposed pistons and crankshafts introduces serious problems. There is great difficulty in the design of rocker bearings capable of carrying the heavy loads inevitable at the pivots. This problem is made more acute because these bearings are subject to oscillating movement only, and in a two-stroke engine the loading on them is unidirectional. Therefore, the maintenance of a lubrication film between the bearing surfaces is difficult.

In the Hill engine, these problems were overcome by the employment of needle roller bearings, both at the pivots and the ends of the rockers. The disadvantages of needle roller bearings are, of course, well known, but now that efficient cages have been developed for them, their adoption for this application would appear to be justifiable.

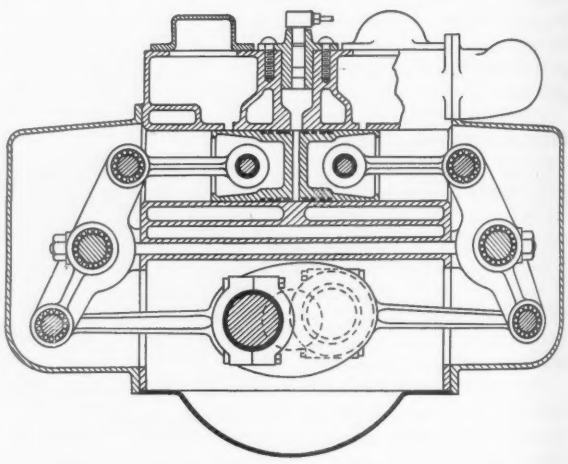


Fig. 1. Needle roller bearings are employed both at the pivots and the ends of the rockers of the Hill engine, of American origin

Sulzer

About 1936, the Sulzer internal combustion engine was introduced. It was an improved, high-speed two-stroke type unit, with horizontally-opposed pistons, and a rocker-actuated crankshaft, Fig. 2. The cylinders are arranged in a similar manner to those of the Hill engine, the rockers being coupled at one end to the opposed pistons and at the other to a crankshaft with two throws per cylinder, spaced 180 deg apart.

The Sulzer development constituted a considerable advance in this field. From the illustration, it can be seen that above the scavenge end of each cylinder is a vertical, single-acting, short-stroke scavenging pump, actuated by a light connecting rod from an arm on the adjacent rocker. Other features of this opposed-piston oil engine are rotational

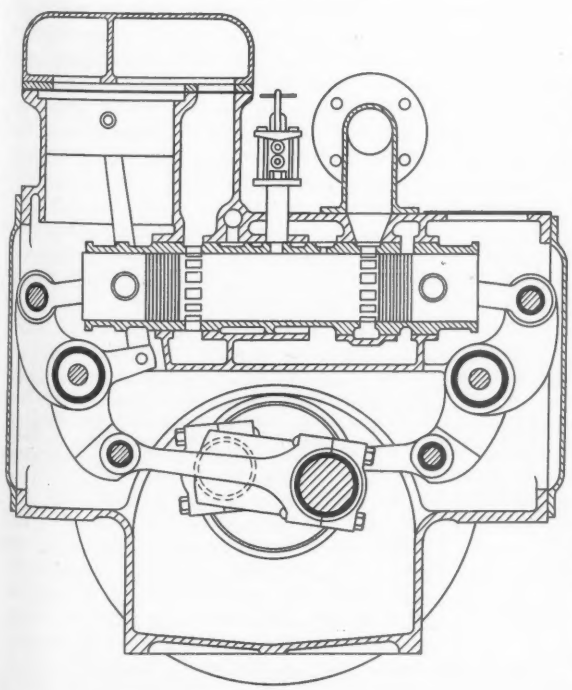
swirl of the incoming air, imparted by tangential ports, and an efficient scavenging system. The bore is 90 mm, and the combined stroke of 240 mm is equally divided between the opposed cylinders. This gives a volume of 1,527 cm³ per cylinder. Maximum rating for operation under intermittent full load conditions is 30 b.h.p. per cylinder at 1,500 r.p.m.

Both the main journals and the big ends are white metal lined. Pistons of composite construction are employed. They have cast iron skirts and their heads are of a special heat resisting alloy. An interesting feature of the engine is that the opposed pistons move slightly out of phase with each other. This phasing is effected by the arrangement of the crank throws so that they are not exactly opposed. The phasing is such that the exhaust ports both open and close before the inlet ports. Fuel injection, lubrication, water circulation and starting gear are more or less conventional.

Commer

A later development was the Commer TS3 diesel engine, described fully in the August, 1954, issue of *Automobile Engineer*. One aim in the design of this unit was at keeping the overall height as low as possible, so that the engine could be used in underfloor installations, while at the same time giving ready accessibility for servicing. A diagram illustrating the general arrangement of this engine is shown in Fig. 3. The unit has three cylinders, in which are opposed pistons, and it operates on the two-stroke principle. One of the difficulties that had to be overcome was the balancing of the rockers, which, having offset arms, are necessarily of heavy section. The problem was rendered more acute by the fact that the space available is restricted. This engine incorporates Clevite bushes of generous proportions for all the bearings of the rockers. These bearings have given every satisfaction. An interesting feature of the engine is an exhauster pump actuated by a rod connected to the lower end of one of the rockers.

Fig. 2. An interesting feature of the Sulzer engine, designed in Switzerland, is the vertical, single-acting, scavenge pump, actuated by a connecting rod and the arm of the adjacent rocker



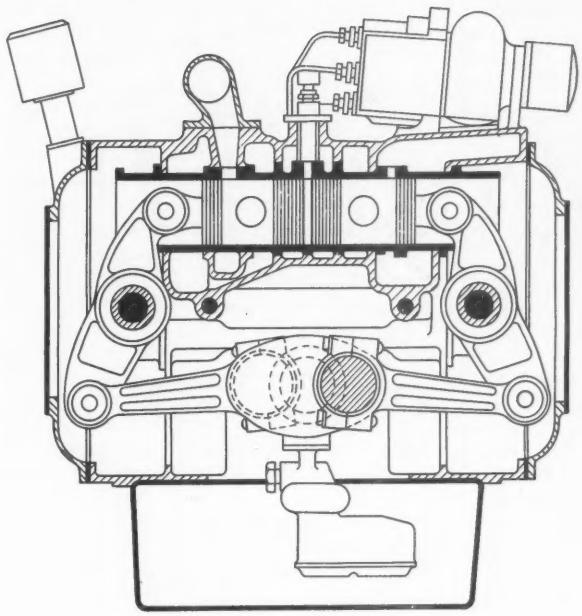


Fig. 3. The Commer TS3 diesel engine is being produced in this country in large quantities for underfloor installation

The dimensions of this engine are similar to those of the Sulzer and the Hill units. A bore of 3·25 in and a stroke of 4·0 in have been adopted. This gives a swept volume of 199 cm³ (3,255 cm³). The firing order is 1, 2, 3. At 2,400 r.p.m., the maximum output of 90 b.h.p. is obtained, while the maximum b.m.e.p. of 94 lb/in² is obtained at 1,350 r.p.m. The torque curve is relatively flat, a value of approximately 250 lb-ft being maintained at approximately 1,200-1,500 r.p.m. Although the normal compression ratio is 19:1, its effective value is 16:1. A minimum specific fuel consumption of 0·38 lb/b.h.p-hr is obtained.

Among the noteworthy features of the Commer unit are the adoption of the Kadenacy porting system. With this arrangement the inertia of the outgoing gases greatly assists scavenging, particularly in the concluding stages of the exhaust stroke. Complete scavenging is ensured by the employment of a Roots type blower, which, of course, has no supercharging effect in this application. The inlet ports are opened near the end of the exhaust stroke and are so arranged that the gas flows tangentially from the chest surrounding them into the cylinder. This imparts the swirl to the incoming gases, as they progressively fill the cylinder and, aided by the Kadenacy effect, force the exhaust gases out through the ports that are uncovered by the piston at the opposite end. Thus, the overall flow through the cylinders is uni-directional.

One of the problems to be overcome in the design of a two-stroke engine is the reduction of the rate of heat flow to the piston. In this design, the crown of the piston is to a large extent insulated from the skirt. Thus, a large part of the heat is retained in the combustion chamber; as a result, thermal efficiency is improved and the tendency to the development of diesel knock is reduced.

The forged crankshaft has four main journals and three crank pins, and since the thrusts in the connecting rods are balanced, the loads on the main journal bearings are relatively light. These bearings are of the white metal lined steel shell type. In the big end of each connecting rod, the shell in the half that takes the thrust is lined with a harder bearing metal than that in the other half. This arrangement

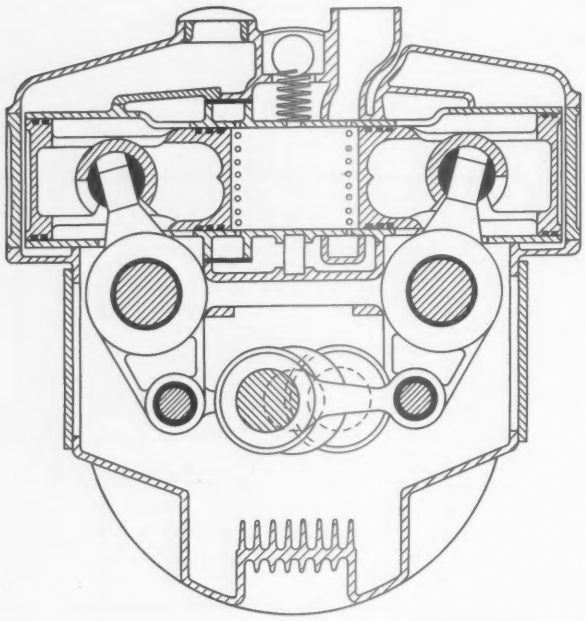


Fig. 4. A noteworthy feature of the Morton engine, designed in New Zealand, is that the complete cylinder and piston assembly can be lifted clear of the remainder of the unit to facilitate servicing. The outer ends of the double-acting pistons effect the scavenging

is particularly suitable for two-stroke engines, because of the relatively constant loading on the rod half of the bearing. However, it is of interest to note that it is also employed on at least one high-performance four-stroke petrol engine.

Morton

The Morton engine has been designed with accessibility for servicing primarily in mind. The opposed pistons actuate rockers, but the layout is different from most, in that one end of each rocker is cylindrical and projects into a hole through the centre of the ball component of a ball-and-socket gudgeon joint. In other words, there are no rods between the pistons and the rockers. The other ends of the rockers are connected by short rods to the crankshaft, which is below the cylinders. This arrangement not only eliminates one set of connecting rods, but also enables the complete cylinder and piston assembly to be unbolted from the crankcase and removed for servicing. The interesting feature of the design is, of course, its ball and socket type gudgeon joints, and one wonders how well they resist wear under all conditions of operation.

Another unconventional feature of the engine is that the pistons are double-ended, their inner ends being of smaller diameter than their outer ones. The large diameter outer ends, of course, are for compressing the gas before it enters the central portion of the cylinder in the normal manner. From the exhaust ports, the gas passes into an annular chamber and thence out through the exhaust pipe on top of the engine. The two cranks for each cylinder are offset slightly to give the required phasing of the opening of the inlet and exhaust ports.

Goodman

The Goodman engine differs from those previously described in that it has two crankshafts and a bank of power cylinders above another bank of charging cylinders, Fig. 5. Each cylinder contains a pair of opposed pistons connected to rockers oscillating about pivots mounted in the crankcase. The rockers each incorporate a third arm, to which is pinned the small end of the connecting rod that actuates the crankshaft. Each crankshaft carries a flywheel, and the two revolve in opposite directions, so that good balance is relatively easy to attain. The two shafts are connected by a chain drive to a spiral bevel gear on one side of the crankcase, which transmits the drive to the output shaft.

In operation, when the pistons in the lower cylinder approach their outer dead centre positions, the inlet ports at one end are uncovered and the cylinders fill with air. As they come together again, the inlet ports are closed and the air is forced through the ring of ports round the centre of the cylinder and thence into a transfer passage. In the meantime, the pistons in the upper cylinder are moving outwards until they uncover the inlet ports at one end and the exhaust ports at the other. Then the air is forced from the transfer passage through the inlet ports and assists the scavenging of the burned gases through the exhaust ports at the other end. Next, the pistons in the power cylinder begin to move inwards again, while those in the compressor cylinder move outwards, and the sequence of operations is repeated. In the illustration, the pistons in the upper cylinder are almost at top dead centre. As in all these engines, the quantity of air delivered by the compressor cylinders is larger than that required to fill the combustion cylinders, so the burned gases are completely scavenged. All the cylinders are jacketed for water cooling.

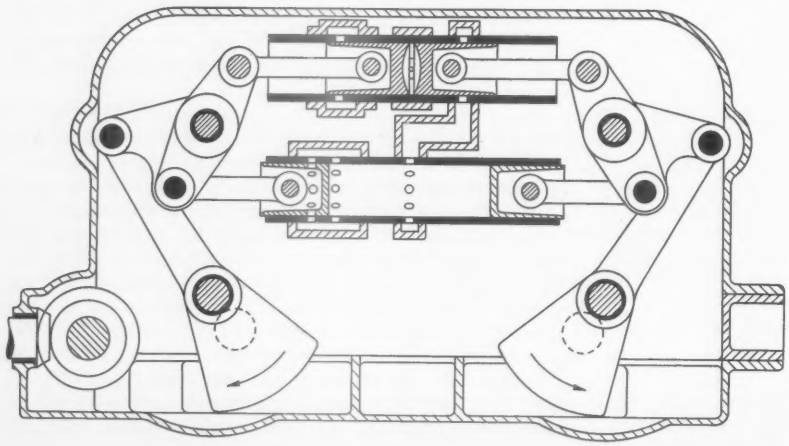


Fig. 5. There are two crankshafts in the Goodman engine, which was designed in this country. It also has two banks of cylinders, one above the other; the lower bank is used solely for charging the upper one

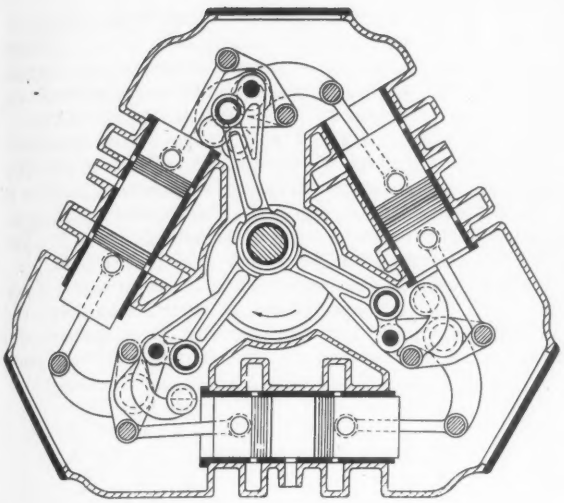


Fig. 6. The Fiala-Fernbrugg engine is said to be undergoing development in Austria for operation with petrol, diesel oil and for special combustion systems; it is also said to be suitable for both air- and water-cooling. Complex linkages connect the crankshaft to the pistons, but the unit has a single-throw crank and no valve gear

Fiala-Fernbrugg

To obtain the maximum amount of space for the accommodation of passengers and also to give a low floor, a number of rear-engine installations have been introduced. For this type of application, the Fiala-Fernbrugg engine, Fig. 6, might be particularly suitable. From the illustration, it can be seen that the cylinders are of the delta layout, that is, their axes form the sides of an equilateral triangle. The crankshaft is rocker-actuated, there being a rocker of complex form at each corner of the triangle. With this arrangement, it is possible for the four strokes of the Otto cycle to take place in one revolution of the crankshaft.

The central crankshaft carries a master connecting rod, on which the big ends of the other two connecting rods oscillate. All three rods are connected at their small ends to two short links actuated by rockers. Each rocker assembly in fact comprises two rockers on a common pivot pin mounted on the engine structure. One end of each of these two rockers is pinned to the adjacent piston rod, and the other to one of the short links, already mentioned, attached to the pin carried in the eye on the extreme end of the connecting rod.

The working cycle of, for example, the lower cylinder in Fig. 7, is as follows. At the end of the exhaust stroke, the two pistons are within 8 mm of each other, in the region of the exhaust ports. As the crankshaft revolves, they move together towards the right, then the right-hand one rapidly accelerates away from the other and uncovers the induction ports. A charge is then drawn in between the separating pistons. Next, both pistons reverse their direction of travel and move towards the left, the right-hand piston moving faster than the left-hand one and compressing the charge, which is fired, at mid-stroke, in an 8 mm compression space. During the power stroke the pistons are forced apart, the left-hand one eventually uncovering the exhaust ports. The right-hand piston does not reach the induction ports, but instead, its direction of travel is reversed and it follows up the other piston to complete the scavenging.

Although the action of this engine mechanism appears to be particularly complicated, the design eliminates all the valve gear, and the valve timing can never deviate from the original setting. Furthermore, the crankshaft is of simple form. The linkage involved can be so dimensioned and its pivots selectively positioned to give any desired relationship between piston displacement and crank rotation, within defined limits.

The diagrammatic illustration, Fig. 7, depicts the action of the various components constituting the linkage system. A crank pin D, on the central crankshaft C, carries the big end of a master rod, on which are pivoted two connecting rods, all three being denoted as E. There are two eyes at the small end of each connecting rod, a primary one F and a secondary one G. The secondary eye is connected to link L pivoted on a pin H fixed to the engine casing, while the primary pivot pin F is connected to the curved link J and the straight link K.

A pin at M connects the curved link to a two-armed rocker R, which is jointed at P to the piston rod Q attached to the gudgeon pin in the exhaust piston V_1 operating in the cylinder Z_1. Similar sets of links are connected to the exhaust pistons V_2 and V_3, operating in the cylinders Z_2 and Z_3 respectively. The rocker R is mounted on a pivot T fixed to the engine casing. The intermediate straight link K connects the primary pivot pin F of the master connecting rod E to the pin S, on one end of another two-armed rocker N. At the other end of this rocker N, there is a joint U, connected to the piston rod X that actuates the piston controlling induction at ports B. The two-armed rockers R and N are coaxial.

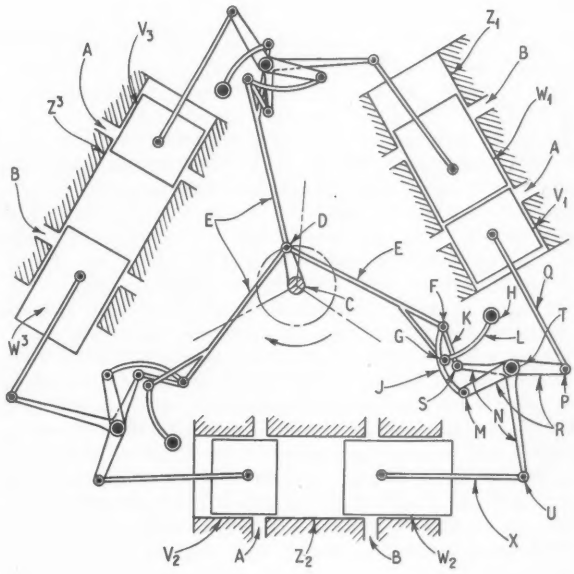


Fig. 7. Diagram showing the principle of operation of the Fiala unit

A typical set of dimensions and angles are as follows. When the crankshaft has rotated through the first 15 deg, as in the right-hand cylinder of Fig. 7, the exhaust control piston V_1 is at a distance of 2·5 mm from the induction control piston W_1, and the exhaust ports A are just closed. Both pistons in the cylinder then move towards the induction ports B, which are opened by the induction control piston W_1 when the crankshaft has revolved 72 deg. At this position, the exhaust control piston V_1 is 17 mm from the exhaust ports.

During this part of the cycle of operations, that is, from 15 deg to 72 deg, the residual gases, initially confined in a piston spacing of 2·5 mm, are expanded until the piston spacing is 56 mm; thus, the pressure is reduced to a value

lower than atmospheric. This gives rise to internal cooling, which helps the oil film to adhere to the bore of the cylinder. At 72 deg of the crankshaft revolution, the induction mixture, or air alone, enters the cylinder and also expands. When the induction control piston W_1 has fully opened the induction ports B, it again moves, together with the exhaust control piston V_1, towards the exhaust ports A. However, the direction of motion of the exhaust control piston is reversed 4 mm before it reaches the exhaust ports A, which, therefore, it does not open, and it then moves back towards the induction ports B. When the exhaust control piston V_1 is 4 mm from the exhaust ports A, the induction control piston W_1 has already closed the induction ports B, at 120 deg of the crankshaft motion.

Next, the induction volume corresponding to a piston spacing of 68 mm is compressed between the pistons W_1 and V_1. At 180 deg of crankshaft revolution, the pistons are at the position of maximum compression, which is 8 mm apart. Then the gas is ignited and forces the two pistons apart until the maximum volume corresponding to a spacing of 71·5 mm is obtained. The exhaust control piston V_1 opens the exhaust ports A at 267 deg of the crankshaft rotation, but the induction control piston W_1 does not open the ports B since during this stroke its outermost position is 5 mm before the induction ports B. Subsequently, during the exhaust stroke, it moves towards the exhaust ports A. The cycle begins again after 360 deg of crankshaft rotation.

It is understood that this engine is being developed in air- and water-cooled forms for petrol, diesel, semi-diesel and special combustion systems. Further, it is claimed that experiments and tests demonstrate the efficiency and durability of these engines, as well as their low power:weight ratio.

PREFERRED NUMBERS

Theory and Practical Application to the Selection of Ranges of Sizes of Products

J. L. KOFFMAN, Dipl. Ing., M.I.Loco.E

EVERY manufacturer who offers his products in a number of sizes has experienced the difficulties associated with the selection of the steps in which the sizes should be ranged. Adherence to the method of determination afforded by the use of preferred numbers facilitates the taking of these decisions and benefits both manufacturers and users. Application of this method of selection has recently been appreciably simplified by the publication of B.S.2045 "Preferred Numbers," which gives ranges of numbers in tabular form. However, since a mere recital of a series of numbers will scarcely make their use clear, let alone attractive, a discussion of some of the considerations leading to their adoption may be of interest. Such a discussion can best be illustrated by typical examples of applications of the system.

The sensitivity of a man in detecting an increase of weight supported by his hand was extensively investigated about a century ago by the physiologist Weber, and his researches were further extended by Fechner, who made some 28,000 additional tests. Their findings were summarized in the Weber-Fechner law, which states that a change of weight can be detected if the increment is such that the heavier weight amounts to at least 1·26 times the preceding one; or *inter alia*, since 1·26 = antilog of 0·1, the sensitivity is proportional to the logarithm of the excitation. This law was subsequently found to apply also to human sensitivity to variations of sound and light intensity. In the case of sound, one decibel, dB, represents an increase of 1·26, two dB $1{\cdot}26^2 = 1{\cdot}59$, say 1·6, three dB $1{\cdot}26^3 = 2$, four dB $= 1{\cdot}26^4 = 2{\cdot}5$, and so on. Thus, our sensitivity or ability to distinguish between two given physical stimuli follows a geometrical series, and it is therefore natural for preferred numbers to follow such a series. This was fully appreciated by Col. Charles Renard who, in about 1873, used preferred numbers for the standardization of cable sizes for captive observation balloons of the French Army. Later, preferred numbers were used by Androin for the choice of cutting speeds of machine tools.[1, 2, 3]

Fundamentally, the requirements that should be met by a system of preferred numbers are that they should fit into the decimal system, that the choice should be such that doubling and halving of sizes is possible, the numbers should also be such as to form a geometrical series. Mathematically, the result is that the fundamental numbers R of the system should form integral powers of both 2 and 10; so:

$R = \sqrt[y]{2} = \sqrt[z]{10}$ (where y and z are integers)

$(1/y) \log 2 = (1/z) \log 10$

$y = (\log 2/\log 10)\ z = 0{\cdot}301\ z \approx 0{\cdot}3\ z$

and $10\ y = 3\ z$

The solution is:

y =	3	6	9	12	15
z =	10	20	30	40	50

Since the obvious choice is z = 10 the fundamental equation is

$\sqrt[3]{2} = \sqrt[10]{10} = 1{\cdot}25$

Values of z = 20 and z = 40 give finer steps: $\sqrt[20]{10} = 1{\cdot}12$ and $\sqrt[40]{10} = 1{\cdot}06$ respectively, whilst a coarser series will be obtained if the steps are $\sqrt[5]{10} = 1{\cdot}6$.

Thus the steps in the R10 series, of Col. Renard, are 1·25, and all the values in the series can be written and memorized as follows: the values 1, $\sqrt{10} = 3{\cdot}15$ and 10; the full multiples of 1, that is, 2, 4 and 6; full fractions of 10, that is, 5, 2·5 and 1·25; and half and double 3·15, which, of course, are 1·6 and 6·3 respectively. The entire series is:

R5	1	1·25	1·6	2	2·5	3·15	4	5	6·3	8	10
log R5	0·0	0·1	0·2	0·3	0·4	0·5	0·6	0·7	0·8	0·9	1·0

For the R20 series the step value is 1·12. We also have $\sqrt{2} = 1{\cdot}4$ and double this value, that is 1·12, 1·4, 1·8, 2·24, 2·8, 3·55, 4·5, 5·6, 7·2 and 9 and these values can be sandwiched between the appropriate values of the R10 series to make the R20 series. In addition, every basic R series includes the reciprocal values. For example, the R10 series includes:

$\frac{1}{1}$	$\frac{1}{1{\cdot}25}$	$\frac{1}{1{\cdot}6}$	$\frac{1}{2}$	$\frac{1}{2{\cdot}5}$	$\frac{1}{3{\cdot}15}$	$\frac{1}{4}$	$\frac{1}{5}$	$\frac{1}{6{\cdot}3}$	$\frac{1}{8}$	$\frac{1}{10}$
1	0·8	0·63	0·5	0·4	0·315	0·25	0·2	0·16	0·125	0·1

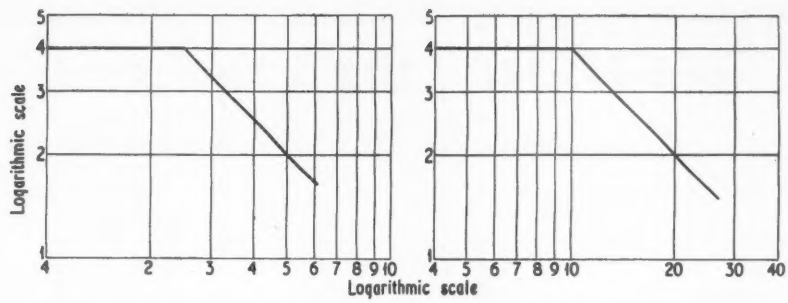


Fig. 1. Right: Illustration showing how the preferred numbers system can be applied for the conversion of the conventional type of squared graph paper for use as the logarithmic type

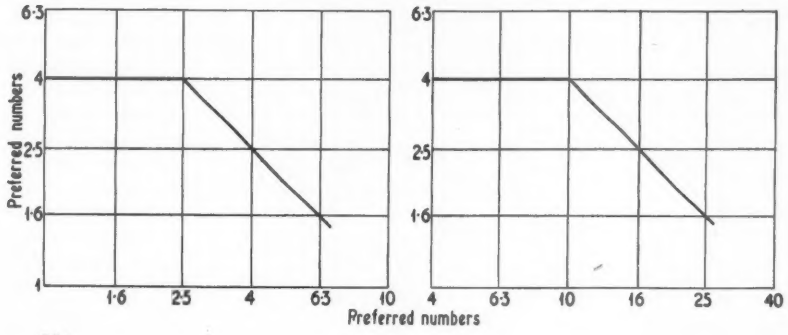
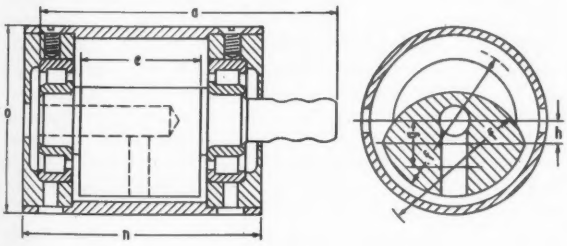


Fig. 2. Below: Design for a series of rotary vibrators dimensioned in accordance with the preferred numbers system

Size	Force tons	R.P.M.	a mm	e mm	f mm	g mm	h mm	n mm	o mm
1	0·08	20,000	50	20	25	7·2	3·6	40	32
2	0·125	16,000	63	25	32	9·3	4·65	50	40
3	0·2	12,500	80	32	40	11·5	5·75	63	50
4	0·315	10,000	100	40	50	14·4	7·2	80	63
5	0·5	8,000	125	50	63	18·3	9·15	100	80
6	0·8	6,000	160	63	80	23·0	11·5	125	100
7	1·25	5,000	200	80	100	29·0	14·5	160	125
8	2·0	4·000	250	100	125	36·5	18·25	200	160



Some further relationships are given below:

$1{\cdot}06^{40}=10$	$1{\cdot}12^{40}=100$	$1{\cdot}18^{40}=1{,}000$
$1{\cdot}12^{20}=10$	$1{\cdot}25^{20}=100$	$1{\cdot}25^{30}=1{,}000$
$1{\cdot}25^{10}=10$	$1{\cdot}6^{10}=100$	$1{\cdot}4^{20}=1{,}000$
$1{\cdot}6^{5}=10$	$2{\cdot}5^{5}=100$	$1{\cdot}6^{15}=1{,}000$
$2{\cdot}5^{2.5}=10$	$3{\cdot}15^{4}=100$	$2^{10}=1{,}000$
$3{\cdot}15^{2}=10$		

$1{\cdot}06^{41}=10{\cdot}6$	$1{\cdot}06^{81}=106$
$1{\cdot}12^{21}=11{\cdot}2$	$1{\cdot}12^{41}=112$
$1{\cdot}25^{11}=12{\cdot}5$	$1{\cdot}25^{21}=125$
$1{\cdot}6^{8}=16$	$1{\cdot}6^{11}=160$
$1{\cdot}8^{5}=18$	$1{\cdot}8^{6}=180$
$3{\cdot}15^{5}=31{\cdot}5$	$3{\cdot}15^{5}=315$

It should be mentioned that 6·3 was adopted as a preferred number in preference to 6·4 because it is nearer to 2π, and because 63^2 is nearer to 4,000. Also, $\sqrt{10}=3{\cdot}15$ is half 6·3.

Reference to the R5 series shows that associated with every preferred number there is a logarithm. This enables conversion of standard squared paper into logarithmic type to be made readily, by the simple expedient of writing the values of preferred numbers against the squares, as shown in Fig. 1.

The use of preferred numbers can be illustrated by the following example.[1] A number of vibrators were required for the determination of fatigue properties of vehicle and machine components. Considerations relating to space requirements, ease of operation and prime costs led to a decision in favour of rotary unbalance type vibrators. The range of forces was limited from about 20 lb to 2 tons, and the range of frequencies from 4,000 to 20,000 c/sec. Of course, the vibrators had to be simple to make, robust, easy to maintain, and readily applied for the testing of a wide variety of components. The basic design of the vibrator finally adopted, Fig. 2, clearly shows the simplicity of the arrangement. A roller bearing at each end carries the rotor, and a flexible shaft, made from high-pressure rubber hose, transmits the drive from the electric motor. The shaft is drilled at one end so that, should forced cooling be necessary at high speeds, air from an external supply can be blown through it and thence radially through the rotor.

It was decided that the vibrators should have unbalanced-force steps of $n=1{\cdot}25^2=1{\cdot}61$, and so the R5 series was employed. The overall length of the units followed the R10 series, in steps of $m=1{\cdot}25$, while the masses of the units were determined in terms of $q=1{\cdot}25^3=2$, the same law applying to the out-of-balance masses. Maximum speeds, which were to be the resonance speeds of the tests, were stepped in terms of $p=1/1{\cdot}25=0{\cdot}8$. The main design data for the eight units are shown in the table under Fig. 2. Metric dimensions were used because they enabled the sizes to be determined readily. Since the main dimensions of the basic design for the Size 4 unit were preferred numbers, the corresponding dimensions of the other units also were preferred numbers. A study of this table shows how harmony and simplicity was obtained in what might otherwise have been a cumbersome series. The saving effected in design and development time hardly needs stressing. It is of interest that vibrators of a preferred numbers series, when running at the resonance frequencies of similar structures, set up identical stresses, both in the structures and in the vibrators.

Fig. 3. Right: The proportions of this high tension current warning sign are based on the principle of preferred numbers

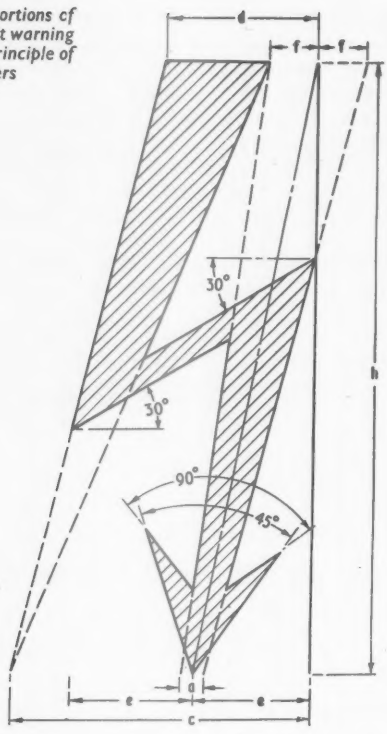
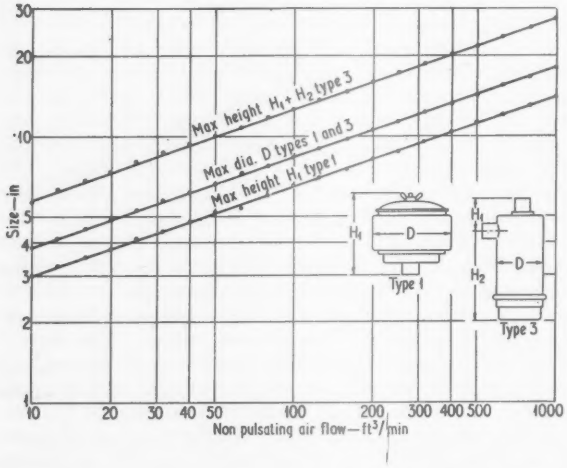


Fig. 4. Below: Air filter sizes based on preferred numbers



The units can be driven by D.C. motors fed from a Ward-Leonard set, but because of the wide range of speeds required, gears might have to be used. Here again, the determination of gear ratios can be made automatically by the use of preferred numbers. For example, three simple transmissions, accommodated in identical housings, and suitable for coupling at either end, might be employed. The gear ratios, to conform with preferred numbers, are 1·25, 2 and 8. With these, it is possible to obtain a total of 15 ratios, all of which fit into the R10 series, as follows:

	1·25	$8\times1\cdot25/2=$	5
2/1·25	$=1\cdot6$	$8/1\cdot25=$	6·3
	2		8
$2\times1\cdot25$	$=2\cdot5$	$8\times1\cdot25$	$=10$
$8/(2\times1\cdot25)$	$=3\cdot15$	$8\times2/1\cdot25$	$=12\cdot5$
8/2	$=4$	8×2	$=16$

$$8\times1\cdot25\times2=20$$

The use of preferred numbers for the standardization of signs is demonstrated in Fig. 3, which is an illustration of a high-tension warning sign, DIN 40 006. If the height h = 100 mm, then a = 4 mm, c = 50 mm, d = 25 mm, e = 20 mm and f = 8 mm. Again, if h = 63 mm, than a = 2·5 mm, c = 32 mm, d = 16 mm, e = 12·5 mm and f = 5 mm. Thus, for any dimensions of h, the values of the other dimensions follow a preferred numbers series, in this case,[4] it is R10.

British Standard 2806:1956 is an example of a recent application of preferred numbers to an industrial standard. This Standard is entitled "Limiting Dimensions of Air Filters for I.C. Engines and Compressors other than for Aircraft." It embraces oil-bath, oil-wetted and fabric element air filters, designed for the air flows ranging from 10 to 1,000 ft³/min. Preferred numbers were applied to simplify the problem of the specification regarding the stepping of air flow quantities and the main dimensions of the individual filters. The air flow values were stepped in accordance with the R10 series, while the information available on filter dimensions was analysed in detail as the basis for dimensional standards. This analysis indicated that the sizes should follow approximately a geometrical progression, not unlike the R numbers. However, while most of the available data related to filters of medium capacity of about 150 to 250 ft³/min, there was not a great deal of information available on units at each end of the range.

For the oil bath type air filters, agreement was first reached in respect of the dimensions of the units designed to accommodate flows of 150 ft³/min. These were then used as the basis for the determination of the dimensions of the other units. Some of the main dimensions are shown in Fig. 4. From the slope of the lines connecting the relevant values, it can be seen that the steps follow the R10 series, though the heights and diameters do not conform with preferred numbers. This lack of conformity arose mainly because of the difficulty of obtaining a successful correlation when the English system of dimensions is used. Nevertheless, the application of preferred numbers in this case was particularly useful in obtaining agreement on the main course of action in regard to the standardization of a wide range of engine accessories.

Oil filters, fuel filters, pulleys and belts are particularly amenable to standardization on these lines. Benefit could also be derived from the standardization of the components of engine cooling systems in such a way that their sizes and performance data are regulated on the basis of the preferred number system. This applies particularly to fan sizes and flow volumes, fan speed, radiator and radiator element sizes, oil coolers, as well as coolant and oil pumps. So far as the vehicle is concerned, wheels and tyres could undoubtedly be standardized advantageously in this manner; so also could heaters and other accessories, and even complete engines.[1] Preferred numbers have been employed for the standardization of heavy turbo-generators and a complete range of turbo-blowers.[5] It is to be hoped that the automobile industry will not neglect this convenient and effective tool of standardization, the benefits of which are apparent to all who have used it.

The author would like to acknowledge his great indebtedness to Prof. Dr. S. Berg, from whose publications on preferred numbers he has learned so much and talks with whom have always provided fresh stimuli in this field.

Bibliography

1. S. BERG: "Angewandle Normzahlen," *Beuth-Verlag*, Berlin, 1949.
2. O. KIENZLE: "Normzahlen," *Springer Verlag*, Berlin, 1950.
3. J. E. SEARS: "Report on the Selection of Ranges and of Types and Sizes (Preferred Numbers)," *B.S.*1638:1950.
4. M. REIDEL: "Normzahlen, Normasse," *Verlag Technik*, Berlin, 1951.
5. A. WEISSLEDER: "Verdichterbau in der Deutschen Demokratishen Republik," *Maschinenbautechnik*, Vol. 4, 1955.

WIMET ECONOTIP TOOLS

Throw-away Carbide Tip Eliminates Re-servicing and Reduces Idle Time

A NEW range of tools announced by the Wickman Wimet Division, Torrington Avenue, Coventry, provides what is probably the most outstanding change in tooling methods since the introduction of the carbide tip. Designed on the principle of the clamped-tip tool, already well established in industry, the new tool consists of a shank or holder to which a carbide tip and a separate chip curler are secured in a prepared location by means of a single socket screw. This method eliminates the need for tool re-servicing. As a cutting edge becomes work-dulled, the tip is released and turned round or turned over to present a new sharp cutting edge. When the eight edges on the square tip or the six edges on the triangular tip have been used, the tip is simply discarded and a new tip inserted.

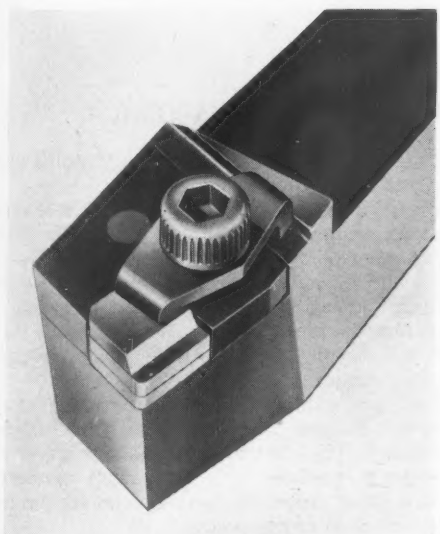
Since it is unnecessary to remove the tool to renew the cutting edge, tool settings remain undisturbed and unproductive time taken up in resetting tools is reduced almost to extinction. The system also ensures that the carbide tip is completely free from brazing stresses, and is thus capable of longer and more consistent service than is sometimes obtained from brazed tools.

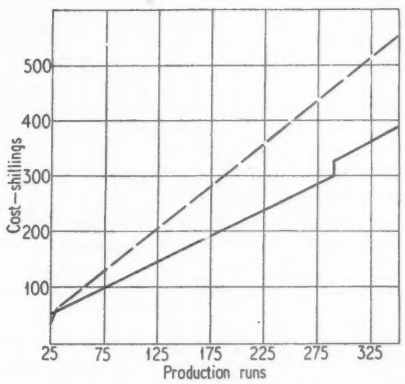
The elimination of the regrinding or lapping process also secures substantial savings in the cost of diamond wheels, normally a very desirable but necessarily an expensive servicing requirement for conventional carbide tools. It also removes the risk of tool failure and shortened life due to incorrect grinding.

Extensive tests have shown that the life of an Econotip holder should be virtually unlimited. However, to allow for the unavoidable hazards of the machine shop, the conservative estimate of a life of 288 production runs has been taken as one of the assumed bases of the calculations that follow. A comparable brazed-tip tool will normally be withdrawn and reground about 25 times before its tip is reduced to unworkable proportions and it has to be discarded.

The accompanying graph illustrating the comparative costs of brazed-tip tooling and Econotip tooling is calculated on the basis of 25 regrinds from the brazed-tip tool and includes labour costs for regrinding at 6d. per regrind, and also diamond wheel usage at 6d. per regrind. The term "production run" on the graph is used to define the period between regrinds of a brazed tool or between changes of cutting edge on an Econotip tool. It must be assumed, of course, that the tools are used for similar applications, and operated under similar conditions.

The 15 deg Econotip tool complete with two carbide tips and a chip curler. Other standard tools have 30 deg and 45 deg approach angles and, with a triangular tip, zero angle





Graph showing comparative costs of a conventional brazed-tip tool and an Econotip tool operating under similar conditions. An assumed replacement of the Econotip holder is made after 288 production runs

To supplement the graph, specific examples are considered. After 32 production runs, the total expenditure on brazed-tip tools would be:

2 tools at 16s. 9d.	.. ..	£1	13s. 6d.
30 regrinds at 1s. 0d.	.. ..	£1	10s. 0d.
Total	.. ..	£3	3s. 6d.

With an Econotip tool, the cost would be:

Holder	.. ..	£1	7s. 6d.
Chip curler	.. .. ..		1s. 9d.
4 tips at 7s. 6d.	.. ..	£1	10s. 0d.
Total	.. ..	£2	19s. 3d.

The point at which the Econotip tool begins to save its cost, therefore, is after about 30 runs. With further comparable use it begins to show a great saving compared with the costs of supply and maintenance of the brazed-tip tool. Comparing the costs after 288 runs, the brazed tools would have cost:

11 tools at 16s. 9d.	.. ..	£9	4s. 3d.
277 regrinds at 1s. 0d.	.. ..	£13	17s. 0d.
Total	.. ..	£23	1s. 3d.

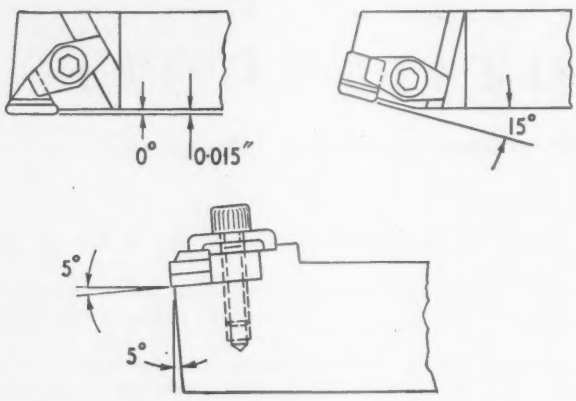


Diagram of zero angle (triangular) and 15 deg (square) tools and the standard 5 deg negative cutting rake

After the same number of runs with an Econotip tool, expenditure would be as follows:

Holder	£1	7s.	6d.
Chip curler		1s.	9d.
36 tips at 7s. 6d.	£13	10s.	0d.
Total	£14	9s.	3d.

This represents a saving of almost 35 per cent on the cost of the brazed-tip tools.

On the unlikely assumption that the holder of the Econotip tool has to be replaced at this stage, a comparison of costs after 400 production runs will illustrate that the disparity in costs is maintained in spite of the expense of the new holder.

With brazed-tip tools, the cost would be as follows:

16 tools at 16s. 9d.	£13	8s.	0d.
384 regrinds at 1s. 0d.	£19	4s.	0d.
Total	£32	12s.	0d.

With Econotip tools, however, the expenditure would be:

2 holders at 27s. 6d.	£2	15s.	0d.
2 chip curlers at 1s. 9d. ..		3s.	6d.
50 tips at 7s. 6d.	£18	15s.	0d.
Total	£21	13s.	6d.

From this point the savings would remain high, about 34 per cent, so that the Econotip tool can be said to give a minimum consistent saving of over 30 per cent as compared with the cost of conventional brazed-tip tools. Throughout these examples use of the "precision" quality tip is assumed. This denotes that the tip is ground not only on the thickness but also on the cutting edges and, therefore, is intended for finish turning. A "utility" tip is also available. This is ground only on the thickness, the cutting edges being left in the sintered condition, and is intended to be used for roughing cuts. By the use of utility tips, half the cost of precision tips is saved, and operation is shown to be even more attractive economically.

Care has been taken in the design of the Econotip tool holder to ensure great rigidity and long life. The holder is made from toughened high-carbon steel, with a seating for the carbide tip and the chip curler provided by a locating piece dowelled to the holder. These are secured to the holder by an unsymmetrical clamp and a socket screw. The seating on the holder is designed to accommodate two tips, the lower tip acting as an anvil for the cutting tip and as a wear-resistant face immediately below the tip to prevent chips of swarf abrading the shank itself. When a chip curler is not required, the tips only can be secured by reversing the clamp. The tip seating is arranged to give a 5 deg negative cutting rake and the normal 5 deg front-to-back angle.

Four styles of tip are available, giving approach angles of 15, 30 or 45 deg with the square tip, and zero deg approach angle with the triangular tip. Two grades of carbide are available at present, Wimet grade N for machining cast iron, non-ferrous metals, and for general-purpose cutting, and Wimet grade XL2 for cutting steel at high speeds. To distinguish between the grades, the grade N tips are marked with a small circular indentation. Depths of cut up to $\frac{1}{4}$ in can safely be taken with these tools, subject to the usual conditions governing the use of carbide tools.

Apart from the economic benefits outlined earlier, there are other advantages deriving from the use of Econotip tools. Though savings of time cannot be assessed with the same exactness as monetary advantages, the fact that the tools can be provided with a fresh cutting edge without disturbing their settings should prove of considerable benefit to most users. Elimination of brazing stresses and also of the problems and risks of grinding are further factors that contribute to the sum of advantages which, in total, present the possibility of substantial economies to users of carbide tools. Manufacturing arrangements have been made to supply the tools and tips on a return delivery service.

SELECTIVE SOLVENTS FOR INDUSTRIAL CLEANING

THREE types of "Freon" solvents are now being marketed by the Du Pont Company, Wilmington 98, Delaware, U.S.A., for the removal of oil, grease, and dirt from instruments and mechanisms without risk of damage to delicate metal parts or such items as electrical insulation. In addition to their "selective" characteristic they are also classified as "safe," since they are non-inflammable and non-explosive and can be used in open workshops without fire hazard. They are non-toxic, and as regards operating personnel, are rated as the safest solvents currently available.

The most important use to date has been the cleaning of electric motors, electrical and electronic instruments and laboratory equipment. In the past there had been a tendency for solvents to attack the insulation on wiring and to weaken it to an extent likely to result in shorting or breakdown in subsequent service. Three years of testing indicate that "Freon" solvents will not soften, craze, or dissolve any of the commonly used insulation materials.

Other applications include their use as safe and efficient heat transfer mediums in laboratory chill baths (instead of flammable and explosive acetone) and as an additive to other solvents to decrease their flammability, or to change their solvency or boiling point for specific purposes. Such additions must be precisely formulated to assure that flammability will be reduced to provide safety under normal operating conditions.

"Freons" are stable chemical combinations of carbon, chlorine, and fluorine. The three Du Pont solvents are designated MF, TF, and BF, with boiling points at 75, 118, and 199 deg F respectively. This range renders them suitable for either vapour degreasing or immersion methods in mechanical cleaning equipment.

The Hookes Joint

Its Mechanics Analysed by the Use of Simple Trigonometry and Ordinary Descriptive Geometry

W. STEEDS, O.B.E., A.C.G.I., B.Sc.(Eng), M.I.Mech.E.

THE kinematics of the Hookes, Cardan, or ordinary universal, joint are dealt with in most text books on the kinematics and the theory of machines. In these works, expressions giving the angular velocity and acceleration of the driven shaft in terms of the angle between the shaft axes are derived for the conditions of constant input velocity. However, the mechanics of the joint, that is the relationships between the torques in the shaft and the forces and moments acting on the components of the joint, do not seem to have received any consideration, at least not in the English language, until they were dealt with by Evernden in his paper, "The Propellor Shaft or Hooke's Coupling and the Cardan Joint", published in the *Proceedings of the Institution of Mechanical Engineers*, October, 1949. In his analysis Evernden makes use of spherical trigonometry, a subject with which many mechanical engineers are not acquainted, so the results obtained have to be accepted without the analysis being fully understood. It is thought, therefore, that a derivation of Evernden's results, which employs only simple trigonometry and the ordinary descriptive geometry used by draughtsmen will be of interest.

Fig. 1 shows a joint with the fork A of the input shaft lying in a plane perpendicular to the plane of the paper and the fork *B* of the output shaft consequently lying in the plane of the paper. A point *C* lying on the axis of the pin of the "cross" or "spider" which engages the fork *A* describes a circle whose plane is the line C_1CC_1 and which is seen in the end view, as the circle *DEFG*. The corresponding point *H* of the other arm of the cross describes a circle whose plane is HCH_1 and which is seen in the end view as the ellipse *DKG*. When the fork *A* is turned through an angle β so that *C* comes to be at *E*, then the other fork will turn through an angle ϕ about its own axis but, in the end view, will appear to turn through the angle β so that *H* comes to *K*. The true value of the angle ϕ is obtained by swinging the plane HCH_1 back into the plane C_1CC_1. The point *K* then comes to *F* and angle $LOF = \phi$. Then

$$\tan\phi = \frac{OM}{FM} = \frac{OM}{KM/\cos\alpha} = \tan\beta\cos\alpha \qquad (1)$$

Differentiating this with respect to time gives

$$\sec^2\phi\frac{d\phi}{dt} = \cos\alpha\sec^2\beta\frac{d\beta}{dt}$$

$$\text{or}\ \frac{\omega_2}{\omega_1} = \cos\alpha\left(\frac{\sec\beta}{\sec\phi}\right)^2 = \frac{\cos\alpha}{\cos^2\beta}\left(\frac{1}{1+\tan^2\beta\cos^2\alpha}\right)$$

$$= \frac{\cos\alpha}{\cos^2\beta+\sin^2\beta\cos^2\alpha}$$

$$= \frac{\cos\alpha}{1-\sin^2\beta\sin^2\alpha} \qquad (2)$$

Consider T_1 to be the torque applied to the driving shaft, and T_2 the torque that is transmitted by the driven shaft. Then, since the rate at which work is put into the input side of the joint, neglecting friction losses which are extremely small, is equal to the rate at which work is got out of the driven side, we have:

$$T_1\omega_1 = T_2\omega_2$$

$$\text{so that}\ \frac{T_2}{T_1} = \frac{\omega_1}{\omega_2} = \frac{1-\sin^2\beta\sin^2\alpha}{\cos\alpha} \qquad (3)$$

In the position of the joint shown in Fig. 1 the torque T_1 is balanced by the couple due to the forces *P* acting between the pins of the cross and the ends of the fork. This couple is, in the position shown, equal to $(P\cos\alpha)D$, where *D* is the distance between the fork arms, so in this position $P = T_1/D\cos\alpha$. Considering the cross itself, the moment on it due to *P* must be balanced by an equal moment due to the forces between the fork arms *H* and the other arm of the cross. Since the forces *P* are in the plane of the cross, the forces at *H* are also in that plane and act perpendicularly to the paper; their magnitude is equal to *P* so the torque T_2

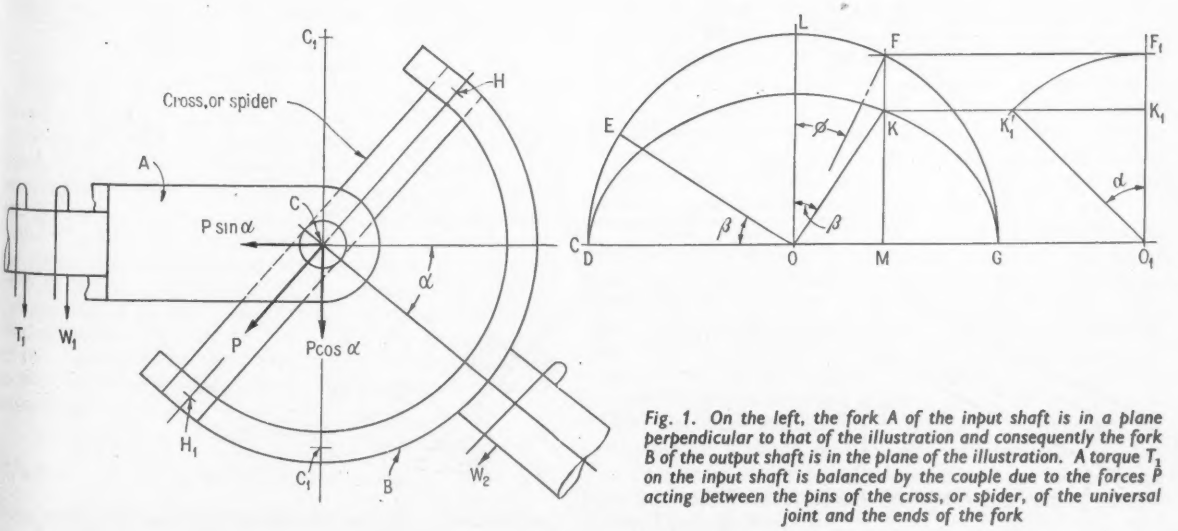


Fig. 1. On the left, the fork A of the input shaft is in a plane perpendicular to that of the illustration and consequently the fork B of the output shaft is in the plane of the illustration. A torque T_1 on the input shaft is balanced by the couple due to the forces P acting between the pins of the cross, or spider, of the universal joint and the ends of the fork

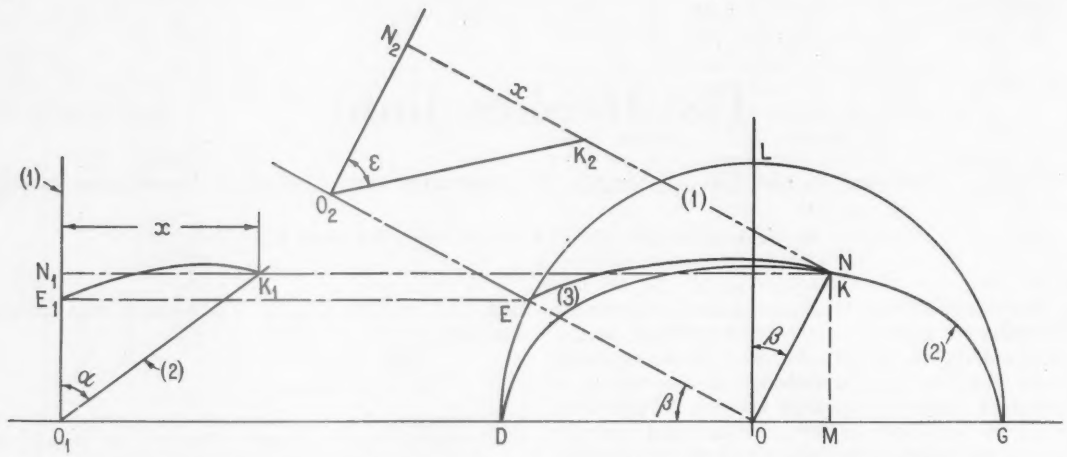


Fig. 2. In this illustration, one half of the cross is represented by the quadrant OEK; the force P, at E, acts in the plane of this quadrant and tangential to the sphere, which is of diameter D and is represented by the semi-circle ELG

is equal to $PD = T_1/\cos\alpha$. This result corresponds to that obtained by putting $\beta = 0$ in equation (3). Reverting to the fork A, it can be seen that the force P has a component $P \sin\alpha$ in the plane of the force, and that this, in conjunction with the corresponding force on the other arm of the fork, produces a rocking couple in the plane of the fork. This couple, which has to be sustained by the bearings that carry the shaft, is equal to $(P \sin\alpha)D$ and thus is also equal to $T_1 \tan\alpha$. Again, however, this is only a particular value for the condition shown, that is, $\beta = 0$. We may now proceed to derive general expressions for the rocking torques in the forks.

Referring to Fig. 2, in which one half of the cross is represented by the quadrant OEK, the force P at E acts in the plane of this quadrant and tangential to the sphere, diameter D, represented by the semi-circle ELG. In order to resolve this force into components lying in the plane (1) of the input fork, that is, the plane of the paper, and at right angles to it, an expression for the true angle between the plane (1) and the plane (3) of the quadrant OEK must be derived. The true value of this angle is seen as ϵ, in the view along the line OE, which lies in plane (1). In this view, x is the perpendicular distance at which the point K lies in front of that plane; this distance is also given by N_1K_1 in the end view. We then have:

$$\tan\epsilon = \frac{x}{N_2O_2} = \frac{x}{NO}$$

but
$$NO = \frac{NM}{\cos\beta} = \frac{N_1O_1}{\cos\beta} = \frac{O_1K_1\cos\alpha}{\cos\beta}$$

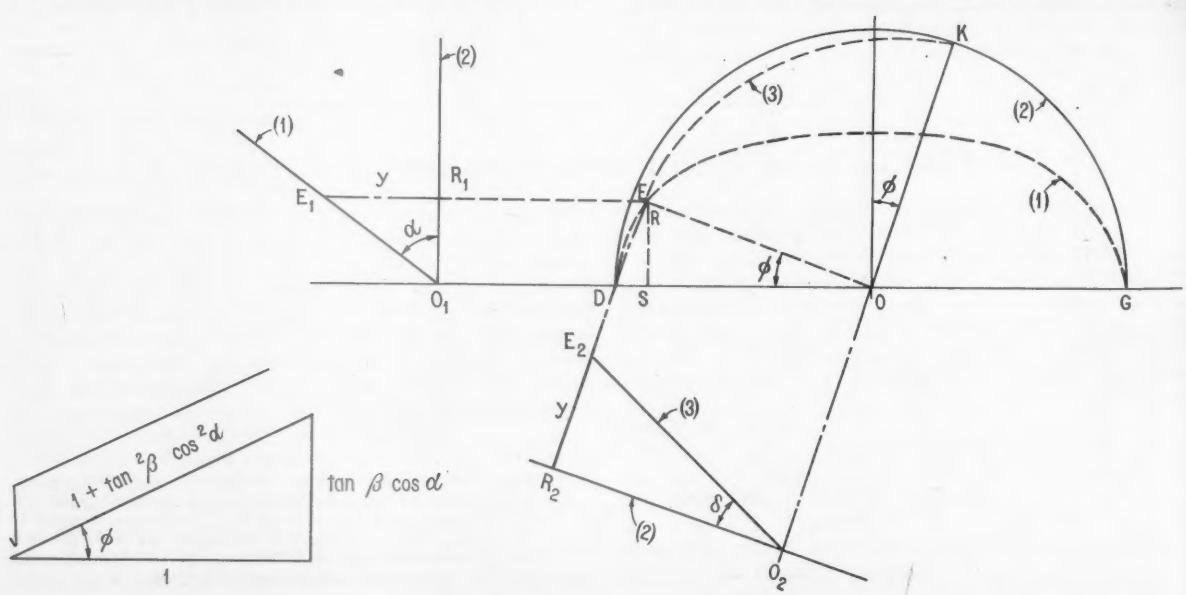
and
$$x = N_1K_1 = O_1K_1 \sin\alpha$$

hence
$$\tan\epsilon = \tan\alpha\cos\beta \qquad (4)$$

In a similar manner the angle between the plane (3) of the quadrant OEK and the plane (2) of the driven fork can be obtained by taking a view along the line KO, which is the line of intersection of these planes. To do this, the plane (2) is first swung into the plane of the paper, as shown in Fig. 3, where the ellipse DKG of Fig. 2 is now seen as the semi-circle DKG. The circle in which the point E moves is now seen as the ellipse DEG, and the quadrant representing the

Fig. 3. Right: The ellipse DKG of Fig. 2 is shown in this illustration as the semi-circle DKG, and the circle in which the point E moves is represented by the ellipse DEG. The side OK of the quadrant representing the cross is in the plane of the diagram

Fig. 4. Left: Diagram illustrating the expression for substitution for the term sin ϕ, to obtain in equation (7) the rocking couple on the output fork



cross has its side OK in the plane of the paper. The point E now lies at a distance y behind the plane of the paper, and the true value of this distance is seen in the end view as E_1R_1, and in the view along KO, as E_2R_2. In this latter view δ is the true angle between planes (2) and (3). Then:

$$tan\ \delta = \frac{y}{O_2R_2}$$

but $$O_2R_2 = OR = \frac{SR}{sin\ \phi} = \frac{O_1E_1\ cos\ \alpha}{sin\ \phi}$$

and $$y = R_1E_1 = O_1E_1\ sin\ \alpha$$

hence $$tan\ \delta = tan\ \alpha\ sin\ \phi \qquad (5)$$

The rocking couple T_{R1} on the input fork is $(P\ sin\ \epsilon)D$ and the input torque $T_1 = (P\ cos\ \epsilon)D$, hence:

$$T_{R1} = T_1\ tan\ \epsilon = T_1\ tan\ \alpha\ cos\ \beta \qquad (6)$$

and the rocking couple T_{R2} on the output fork is $(P\ sin\ \delta)D$

and $$T_2 = (P\ cos\ \delta)D$$

hence $$T_{R2} = T_2\ tan\ \delta = T_2\ tan\ \alpha\ sin\ \phi$$

Now, from equation (1)

$$sin\ \phi = \frac{tan\ \beta\ cos\ \alpha}{\sqrt{1 + tan^2\beta\ cos^2\alpha}} \qquad \text{(see Fig. 4)}$$

and T_2 is given by equation (3).

On substituting for these quantities we get:

$$T_{R2} = \frac{T_1(1 - sin^2\beta\ sin^2\alpha)}{cos\ \alpha} tan\ \alpha\ \frac{tan\ \beta\ cos\ \alpha}{\sqrt{1 + tan^2\beta\ cos^2\alpha}}$$

$$= T_1\ tan\ \alpha\ sin\ \beta\ \sqrt{1 - sin^2\beta\ sin^2\alpha} \qquad (7)$$

Reference to Fig. 5, which is a photograph of a model, may be of assistance in visualizing the orthogonal projections of Figs. 2 and 3.

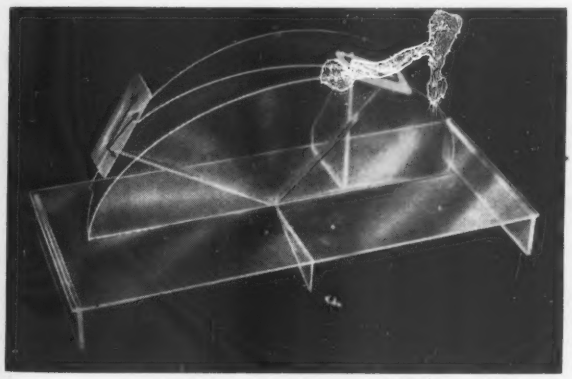


Fig. 5. Model illustrating the orthogonal projections of Figs. 2 and 3

The torques acting on the frame. In Fig. 6 the joint is shown supported in a frame A carried by a ball joint at B. This arrangement has been adopted to demonstrate the actions that have to be transmitted by the frame to the fixed foundations. The couples that are applied to the assembly are the input torque T_1, the reaction T_{2R} of the output torque T_2, and the torques applied by the foundations to the frame. Those applied by the foundations are indicated by T_{FV} and T_{FH}: it follows that their resultant is equal to the resultant of T_1 and T_{2R}. If these are represented by the vectors OC and OD, the resultant is T_F; the torque applied by the foundations to the frame is equal in magnitude and opposite in sense to this resultant, the magnitude of which is given by:

$$T_F^2 = T_1^2 + T_2^2 - 2T_1T_2\ cos\ \alpha$$

Therefore: $$T_F = \frac{T_1}{cos\ \alpha}(cos\ \alpha - 1 + sin^2\beta\ sin^2\alpha) \qquad (8)$$

If the torque on the frame is resolved into components about the vertical axis BV and the horizontal axis BH, these components are given respectively by:

$$T_{FV} = T_F\ sin\ \xi = T_2\ sin\ \alpha$$

$$= T_1\ tan\ \alpha\ (1 - sin^2\beta\ sin^2\alpha) \qquad (9)$$

and $$T_{FH} = T_F\ cos\ \xi = T_1 - T_2\ cos\ \alpha$$

$$= T_1\ sin^2\beta\ sin^2\alpha \qquad (10)$$

These are indicated in the diagram. Since T_F always lies in the plane containing the shaft axes, it is clear that the torque on the frame never contains a component perpendicular to that plane. Consideration will show that the torque acting on the portion A of the frame is the torque T_{R1} and that the torque acting on the portion E is the torque T_{R2}.

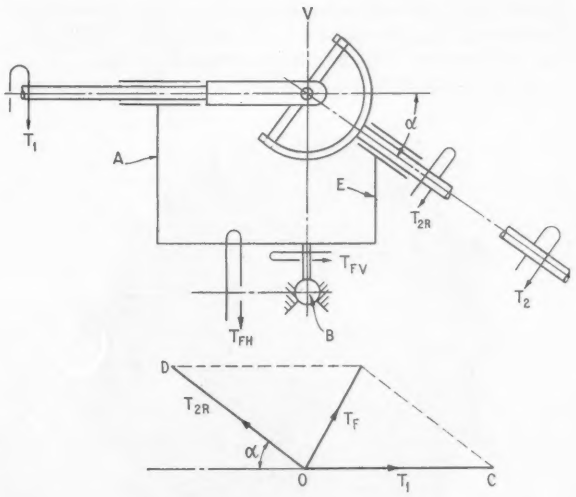


Fig. 6. Diagram showing a universal joint supported in a frame A, which is carried by a ball joint B. This arrangement demonstrates how the reactions are transmitted to the fixed foundations. It can be seen that the torque on the frame does not contain a component perpendicular to the plane in which the axes of the two shafts are situated

Tests for Plastics

PART I of a British Standard for methods of testing plastics (B.S.2782:1956) has been published. It deals with a group of test methods that can be reasonably considered to be of use in the assessment of the effects of temperature on plastics and associated products. The work was prepared with the full collaboration of the British Plastics Federation. Included in it are tests to determine the following properties: crushing strength after heating, deformation in bend under load at elevated temperatures, melting point, cold bend temperature, shrinkage and after-shrinkage, and loss in weight on heating.

When the series is completed, it will include tests for application to moulding and extrusion compounds, synthetic resins and their solutions, semi-fabricated products, such as sheet, thin film, rod and tube, and finished articles in the form of mouldings and extrusions. Many of the methods prescribed in existing British Standards for testing plastics materials will be incorporated in the series. Attempts will be made to rationalize allied methods of testing, which differ only in arbitrary matters, so that a single method will be applicable to a much wider range of materials than at present. Copies of this Standard, price 10s., can be obtained from the Sales Branch, British Standards Institution, 2 Park Street, London, W.1.

THE EUCO MICROMETRIC SPACER

A Device for the Precise Adjustment of the Width of Interlocking Milling Cutters

IN wide slotting or channelling operations, the conventional method of setting up a pair of interlocking milling cutters by means of spacing collars or shims is liable to be laborious and time-wasting. Should it be found necessary to make adjustment after taking a trial cut, the arbor assembly must be dismantled and again assembled and this process must be repeated until the specified machining limits have been met. When a regrind of the cutters becomes necessary the adjustment is, of course, lost and the gang must be reset.

Setting is facilitated and speeded-up by the use of a new micrometric spacer manufactured by Euco Tools Ltd., 44 London Road, Kingston, Surrey. This device is an adaptation of the already established Euco micrometer spacing collar used for ordinary gang-milling operations. As standard, the range of adjustment provided is 0·125 in but spacers can be supplied to meet any range within the capacity of the cutters.

When the adjuster key is withdrawn the cutters are completely unencumbered. Minimum effective width is 1·25 in with inserted-blade cutters and 0·75 in with solid cutters

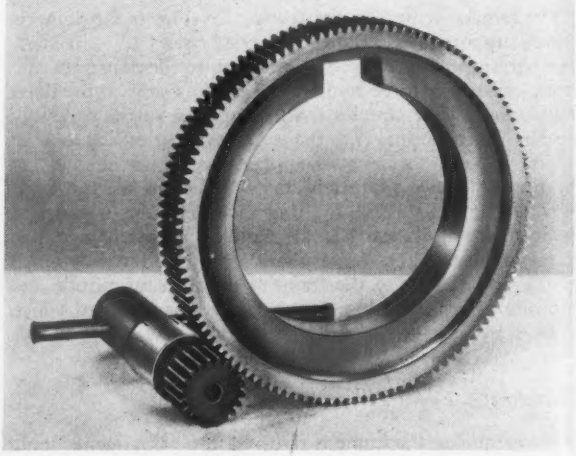
The spacer comprises an inner collar which is key-slotted for the machine arbor and is screw-threaded externally with a micrometer thread. Over this, in screwed engagement, is the outer collar formed as a fine-pitch ring gear. Adjustment of the spacer when assembled between the milling cutters is by means of a key, the end of which is formed as a small pinion to engage the gear teeth on the outer collar. This key takes its bearing in a suitably located hole in the body of one of the cutters.

The shank of the key is machine divided so that in relation to a datum mark on the cutter each division represents a movement of 0·0005 in increasing or decreasing, according to the direction of rotation, the overall width of the spacer. A 360 deg turn of the adjuster key gives a movement of 0·004 in. In order to adjust precisely the effective width of a cutter assembly, therefore, it is necessary merely to slacken off the arbor nut, insert the adjuster key and turn it the required number of divisions in the appropriate direction, and re-tighten the arbor nut to clamp the assembly. The operation can be effected in a period of seconds and, of course, without the previous necessity of disturbing the arbor support or the steadies. When work is found to be approaching dimensional limits and a tool setter is called, adjustment can be made so rapidly that there is no need for the operator to leave the machine and clock "idle time." The ease with which adjustment can be made will minimize any inclination a busy setter may have to postpone resetting when borderline work is being produced; a practice likely to result in an undue percentage of work failing to pass final inspection.

Micrometric spacers are made of a high-grade steel, heat-treated to a tensile strength of 130 ton/in^2 and a Brinell hardness value of 590. The two collars are precision ground on the working surfaces and both internal and external screw threads are ground to ensure an efficient mating fit. Spacers at present available cover arbor diameters from 1·0 in to 2·0 in, but they can be supplied for all standard arbors. With inserted-blade cutters the minimum effective width is 1·25 in, adjustable to 1·375 in. The Galtona cutters shown in the illustration can be supplied with H.S.S., super cobalt H.S.S., Stellite, or carbide-tipped blades. Interlocking cutters of the solid type can also be fitted with these spacers and are available in effective widths down to 0·75 in.

Any apprehension regarding the capacity of the micrometric screw threads to withstand the pressure used in clamping the cutters on the machine arbor is dispelled by the report of an investigation made in relation to these threads on standard Euco gang-milling spacers. This showed that the resistance to rupture of the core of a $\frac{7}{8}$ in B.S.F. thread on a 1·0 in standard arbor of 55-ton nickel-chrome steel was 55,686 lb. For the appropriate spacer in 130-ton steel, with 40 threads per inch of 1·3125 in diameter at the crown and 1·28 in diameter at the root, the shear resistance of ten threads was 223,250 lb if a perfect mating fit was assumed. With a reduction of this figure by 20 per cent to compensate for permissible play between the engaging threads, the resistance of the spacer threads would still be more than three times that of the arbor screw threads.

The assembled spacer together with the withdrawable adjuster key

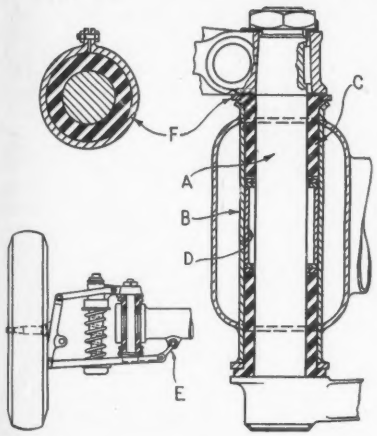


CURRENT PATENTS

A REVIEW OF RECENT AUTOMOBILE SPECIFICATIONS

Wheel suspension mounting

This independent wheel suspension of the wishbone type is mounted on a vertical pin A supported in the end of a tubular frame cross member. The pin is housed in an open tubular element B, with interposed rubber sleeves C positioned by a spacer tube D. Sleeves C are pre-stressed between the pin and tube B and rotation of the pin is prevented by an integral extension E, the end of which is secured through a rubber bushing to a lug on the frame cross member. This extension carries the pivot spindle for the lower wishbone lever.



No. 752417

When assembled, a resilient mounting of this type was found to be not completely satisfactory, since the free end portion of the rubber sleeve was pressed radially outwards by axial forces and the enclosed part of the sleeve resisted only slightly the axial thrust. As a consequence an undesirable softness and unreliability was apparent. This disadvantage is obviated by the provision of a clamping ring F, which is applied around the free end of the rubber sleeve to constrict it and prevent radial expansion. Under axial loading, therefore, the sleeve is compressed throughout its length, and can be adequately pre-stressed to take up both axial and radial forces. A similar clamping ring may be fitted to the exposed end of the lower rubber sleeve, but the need is of less importance in that position. *Patent No.* 752417. *Daimler-Benz A.G.* (*Germany*).

Compounded propulsion unit

The stated claims for this vehicle propulsion means are the attainment of favourable rates of fuel consumption, good thermal efficiency at part loads, and good torque, starting, and acceleration characteristics. A normal change-speed gear will not be necessary; only a simple reversing gear, and possibly an emergency low gear, being required. It comprises a two-stroke cycle, compression ignition engine serving mainly to drive a compressor supplying charging air to the engine. Engine and compressor function as a gas generator, the exhaust gases being delivered as motive fluid to a turbine driving the road wheels through reduction gearing. To enable maximum pressure in the engine to be limited to desirable values to suit running conditions, means for varying the compression ratio are provided.

In the plan of the vehicle shown, the engine A is a water-cooled, vee-type, four-cylinder, valveless unit with the two-stage centrifugal compressor B driven through a two-stage increasing gear from the forward end of the crankshaft. From the exhaust manifolds on the cylinder banks the gases pass to diffuser ducts C which lead to a common insulated gas conduit D arranged in the central longitudinal plane of the vehicle and extending rearwardly to the entry casing of the four-stage turbine E. After being expanded through the turbine, the gases pass to diffusers F and are discharged through tail pipes G.

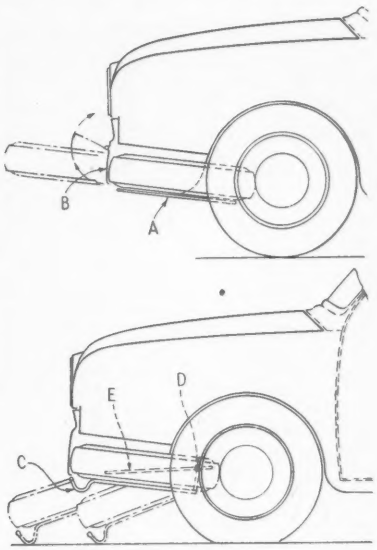
In a modified layout a four-cylinder, line type engine with a single diffuser duct is installed. Details of the arrangement for varying the compression ratio of the engine by means of a slidable plug in the cylinder head are given in another specification, No. 752895. *Patent No.* 752894. *Armstrong Siddeley Motors Ltd.*

Stowage of spare wheel

The disadvantages entailed in the storage of the spare wheel in the luggage compartment—space occupied, difficulty of removal when luggage is carried, and possible soiling of luggage by a wheel dismounted from the vehicle—are avoided by this method of independent stowage. A housing to accommodate the wheel in a substantially horizontal position is provided below the floor of the luggage compartment. At its base the housing has a fixed grille A to support the wheel, while the front consists of a hinged door B that can be swung upwardly to give access. This door may be reinforced to form the centre portion of the bumper and may carry the registration plate. It is furnished with a lock as a protection against theft.

In a modification, the front end of the housing, serving the same purposes of bumper and registration plate, is fixed and may be an integral part of the bodywork. The wheel is supported on a grille C that is hinged on each side at D and latched and locked at the front. The hinges at D may be arranged to slide on rail E to facilitate handling.

The illustrations show the arrangement below the front luggage compartment of a rear-engined vehicle, but the method can be used equally well at the rear. A feature of the invention is that the wheel

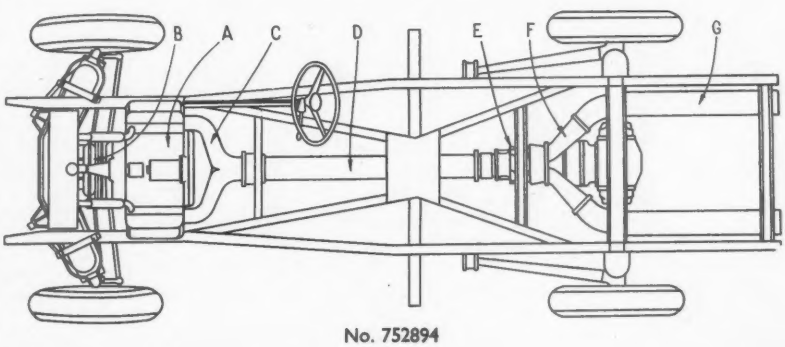


No. 753962

may abut a fixed part of the bodywork or chassis so that it can serve as a shock absorber in the event of violent impact. *Patent No.* 753962. *Regie Nationale des Usines Renault* (*France*).

Preventing the "loading" of grinding wheels

This solid composition has a wide range of application for cutting and abrading tools and also as a lubricant for spinning, deep drawing and extruding operations. When used on a grinding wheel it becomes a highly viscous fluid, penetrating the inner granular structure of the wheel and serving as a floatation medium for dislodged particles of the abrading agent and the



No. 752894

work. It is claimed to resist "break down" due to frictional heat and "throw-off" owing to the peripheral speed of the wheel.

The basic composition is proportioned approximately as follows: tallow 65 lb, paraffin wax 29 lb, beeswax 6 lb, citric acid 1·3 oz, oxalic acid 1·3 oz, potassium citrate 1·3 oz, urea 6·6 oz, Vienna red to colour. Variation of the urea content is practised to adjust the melting point of the composition; either to compensate for the inconsistency in the melting points of different batches of tallow or to adapt the composition to suit specific working conditions. More urea will be embodied for use when spinning steel than when spinning aluminium, and relatively more will be required for rough grinding than for fine, finish grinding.

Urea raises the melting point, paraffin wax functions as a carrier to prevent separation and beeswax serves as a stiffening agent. Citric acid, oxalic acid, and potassium citrate render the composition substantially odourless and also reduce the greasiness and thus facilitate handling. The composition will not deteriorate over extended storage periods. *Patent No.* 753744. *E. A. Fiser* (*U.S.A.*).

Finishing reamer

This compound tool has a primary set of straight lands A, to effect almost the whole of the requisite sizing, followed by a secondary set of left-handed spiral lands B for finishing. The spiral lands are arranged to remove only approximately 0·0002 in and so perform what is virtually a burnishing operation. Since they function in the manner of a screw conveyor they tend to withdraw the chips removed by the straight lands.

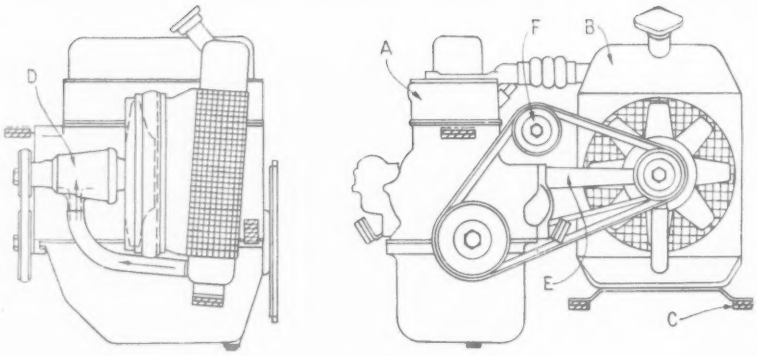
Both sets of lands are provided with carbide tips, those at the entry end being chamfered to provide a lead-in to the hole to be reamed. The shank of the tool is longitudinally grooved at C to furnish conduits for coolant streams. In the example, the spiral angle of the secondary lands is 30 deg. Tip rake and clearance angles are selected to suit the work. *Patent No.* 753836. *Morris Motors Ltd.*

Chassis frame construction

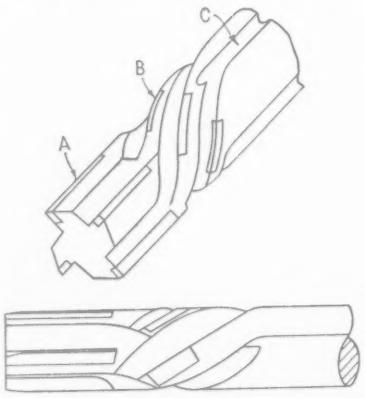
This frame is characterized by a monopiece stamping, with transverse members for the support of the engine and the wheel suspension, and separately fabricated side frames and rear cross members. The stamping is restricted to one end of the frame in order to minimize the dimensions of the blank and the size of the press.

In the example shown, the front end stamping A is throughout of downwardly facing channel section. The side elements are joined near the front by a bowed transverse beam B supporting the wheel suspension and the front of the power unit and near the rear by a cross beam C providing a bearer for the rear of the power unit. Forward extensions D provide attachment points for the front bumper and rearward extensions E form sockets to receive the ends of side members F which are welded in. The stamping is closed by a sole plate G spot welded to marginal flanges. Internally it may be reinforced by brackets, gussets, or bulkheads, not shown. At its junctions with the side elements, the transverse beam B forms cylindrical pockets for the reception of the helical suspension springs, inserted through apertures in the sole plate.

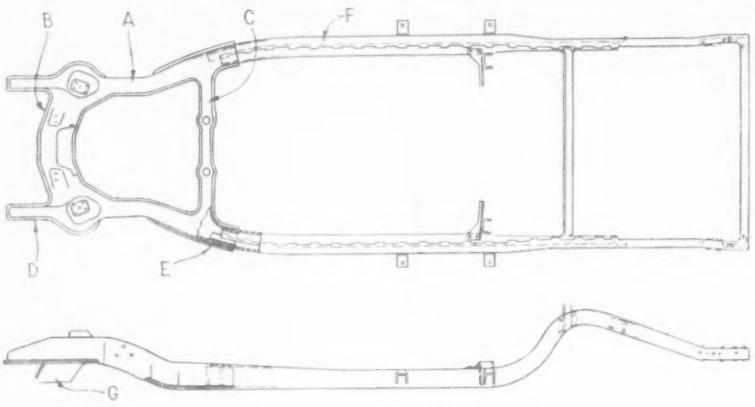
Side members F each consist of two channel pressings overlapping at the flanges and arc-welded together. To avoid stress concentrations at the junction with the stamping A, the channels may be of different length, as shown, or alternatively the socket ends of the stamping may be inclined longitudinally. *Patent No.* 752506. *The Budd Co.* (*U.S.A.*).



No. 753925



No. 753836



No. 752506

Arrangement of rear-mounted, water-cooled engine

While the layout of the coolant system for a forward-mounted engine presents no special problems, difficulties are encountered in the case of a rear-mounted power unit. The space available is usually restricted and the engine is likely to be in an unfavourable position with respect to the air flow generated during the progress of the vehicle. Such considerations have led designers to position a vertical, line-type engine transversely of the vehicle longitudinal axis or to employ an engine having horizontally arranged cylinders. Each of these expedients gives rise to further difficulties.

In the proposed arrangement the line-type engine A is mounted vertically and parallel to the longitudinal axis of the vehicle, and the radiator B is positioned alongside the forward end of the unit and independently supported on the body structure on mountings C. The engine is resiliently mounted and can swing without affecting the radiator. Coolant is circulated by pump D, the casing of which is integral with a bracket arm E rigidly attached to the engine and extending laterally. This arm is hollow and serves as a conduit through which coolant fluid is delivered by the pump to the lower run of the cylinder jacket. The pump shaft carries on its forward end the radiator fan and on its rear end the pulley for the usual triangulated belt drive which includes the generator F.

Advantages claimed for the arrangement are that it does not increase the overall length or height of the propulsion unit; it affords a more even cooling than obtains in known constructions in which the cylinders are positioned horizontally; and engine and radiator assemblies are both easy of access. *Patent No.* 753925. *Fiat Societa per Azioni* (*Italy*).

Necessary Information for Correct Bearing Selection

A drawing or sketch showing layout of the parts involved and positions in which the bearings are to be fitted, giving size of shaft and any dimensions limiting the space available.

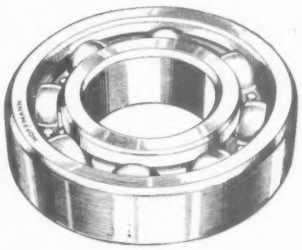
A brief description of the operation of the mechanism if this is not clear from the drawing. Whether the duty is continuous for 24 hours a day or only intermittent. If intermittent, give periods of running and standing.

If the working conditions vary considerably, give the normal duty and also the peak conditions with the frequency and duration of the peaks.

Mention any unusual features such as the possibility of shock or vibration, unbalanced load, high temperature, or the presence of dirt, moisture, or fumes.

Say whether the bearings can be lined up accurately or whether a self-aligning feature is required.

Give the speed and sufficient information to enable the load on each bearing to be calculated.



For Precise Results

use

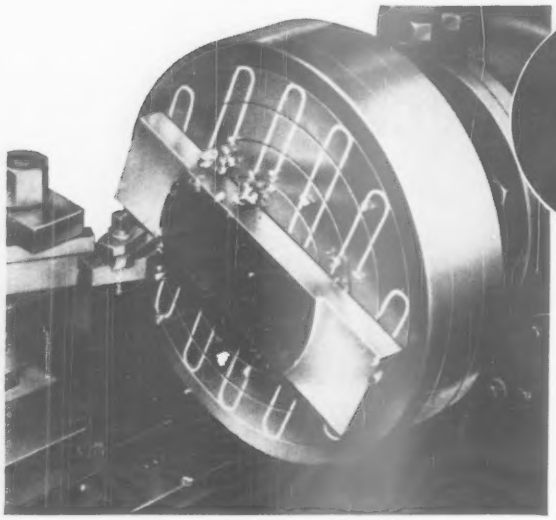
HOFFMANN

BALL AND ROLLER BEARINGS

Our technical experts are solving new bearing applications everyday.

They are completely at your disposal

THE HOFFMANN MANUFACTURING CO. LTD., CHELMSFORD, ESSEX



Permagic gives all round service

Magnetic Lathe Chucks are time savers you cannot afford to be without, in the toolroom or on production, but only "ECLIPSE" provide the security of hold and gain your operator's confidence on difficult jobs and heavier cuts.

• • • • • • • • •

Ask for literature on Magnetic Lathe Chucks.

Eclipse — the only name for magnetic tools

JAMES NEILL & CO. (SHEFFIELD) LTD · ENGLAND

Supplies through appointed "Eclipse" Distributors P.M. 130

FOR Diecastings as strong as steel

ALUMINIUM BRONZE CO. LTD.

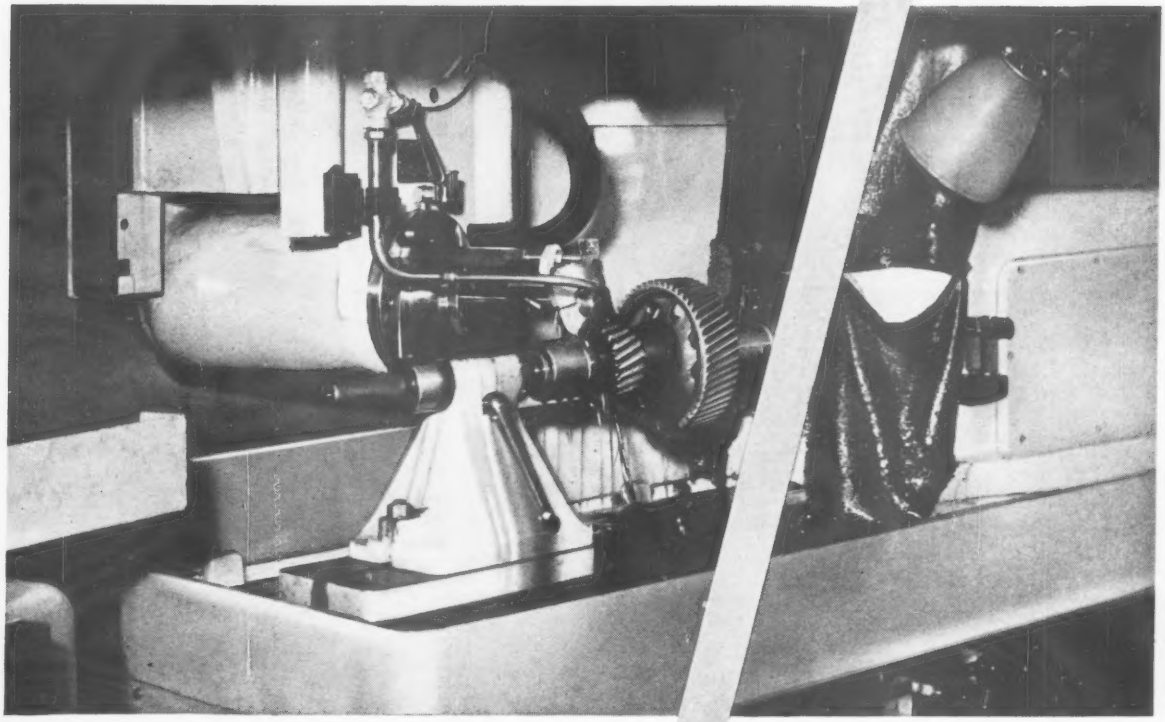
Wallows Lane · Walsall · Staffs.

Telephone WALSALL 2108 (3 lines)
Telegrams "ABCO WALSALL"

"ILOCUT"

CUTTING OILS

and the ROLLS-ROYCE *Dart 510*



Orcutt H.K.N. External Helical Gear Grinding machine grinding low-speed teeth of Dart 510 propeller turbine layshaft at Derby with "Ilocut"

"Ilocut" is Wakefield-Dick's best known range of neat cutting oils. Its high quality never varies—and it is specified by a number of this country's leading production engineers. Rolls-Royce Ltd. use "Ilocut" and many other of our production oils in their Aero Engine Division at Derby in addition to their Crewe, Barnoldswick and Glasgow works.

INDUSTRIAL
WAKEFIELD-DICK
LUBRICANTS

WAKEFIELD-DICK INDUSTRIAL OILS LTD., 67 GROSVENOR STREET, LONDON, W.1

RENOLD
timing chains

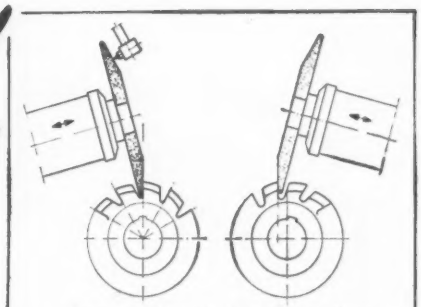
Fitted as standard equipment on the following British motor cars

A.C. · ALLARD · ALVIS · ASTON-MARTIN · AUSTIN · AUSTIN-HEALEY
BRISTOL · CONNAUGHT · COOPER · CITROEN · DAIMLER · DELLOW
FORD · FRAZER-NASH · H.R.G. · HILLMAN · HUMBER · JAGUAR
JENSEN · LAGONDA · LOTUS · LANCHESTER · M.G. · MORGAN
MORRIS · PARAMOUNT · RILEY · ROVER · SINGER · STANDARD
SUNBEAM · TRIUMPH · VAUXHALL · WOLSELEY

RENOLD CHAINS LIMITED MANCHESTER

Here's the way to grind hobs

. . . FOR IMPROVED GEAR PRODUCTION



Correct position of the grinding surfaces

Correct position of the grinding surfaces attained by inclining spindle of grinding head at an angle of 15° so that the effective face of the grinding wheel is at right angles to the table. The dressing diamond is positioned so that perfectly vertical wheel face is presented over the centre line of the cutter.

Highly efficient also for automatic grinding all types of Milling cutters.

KAPP

HYDRAULIC AUTOMATIC UNIVERSAL

TOOL GRINDING MACHINES

ILLUSTRATION SHOWS MACHINE WITH COVERS FOR HEADSTOCK AND SINE BAR REMOVED.

Special sine bar control for precise helix grinding. Quick change indexing system requiring fewer dividing plates. Hydraulic table drive. Adjustable hydraulically operated tailstock. Dust extractor and wet grinding units built into rigid box type bed. All controls conveniently placed.

VAUGHAN ASSOCIATES LIMITED

4 Queen Street, Curzon Street, London, W.1
Telephone : GROSVENOR 8362

Midland Office and Demonstration Room:
WILFORD CRES., NOTTINGHAM. Tel.: Notts. 88008

Driven round the bend by labour costs ?

If spraying is part of the operation, you can save on costly labour time by using the *right* tape for the job.

Here is a THIN, MORE FLEXIBLE Masking Tape which can be quickly applied by the most inexperienced labour and yet ensure a perfect job.

Yes! it's

Sellotape

REGD. TRADE MARK

Masking Tape

for a perfect start to a perfect finish

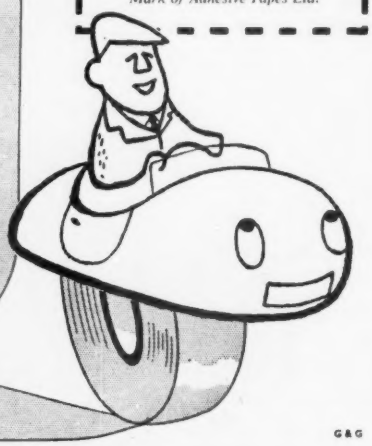
POST TODAY FOR FULL DETAILS
to the Sole Distributors in U.K.
Gordon & Gotch Ltd.
8-10 Paul Street, London, E.C.2
Telephone: BIShopsgate 6511

Please send me more information about Sellotape Masking Tape

Name .....

Address .....

Sellotape is the Registered Trade Mark of Adhesive Tapes Ltd.



G&G

As cool as a . . .

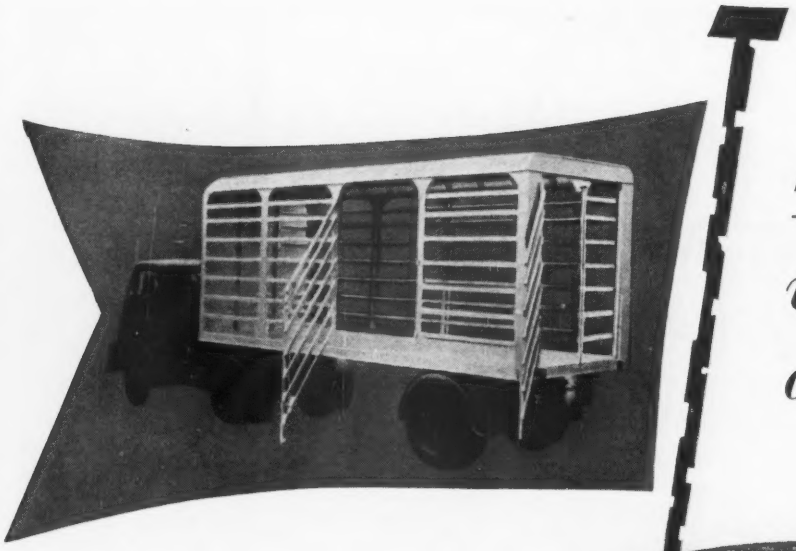
. . . MARSTON RADIATOR

And that means just cool enough to get the finest performance from your engine. For Marston radiators strike the perfect balance between maximum cooling and optimum running temperatures. That's why they are fitted as standard on Britain's finest cars. What better recommendation for the quality and reliability of these famous products?

MARSTON EXCELSIOR LIMITED
WOLVERHAMPTON & LEEDS
(A subsidiary company of Imperial Chemical Industries Ltd.)

ICI

MAR 178A



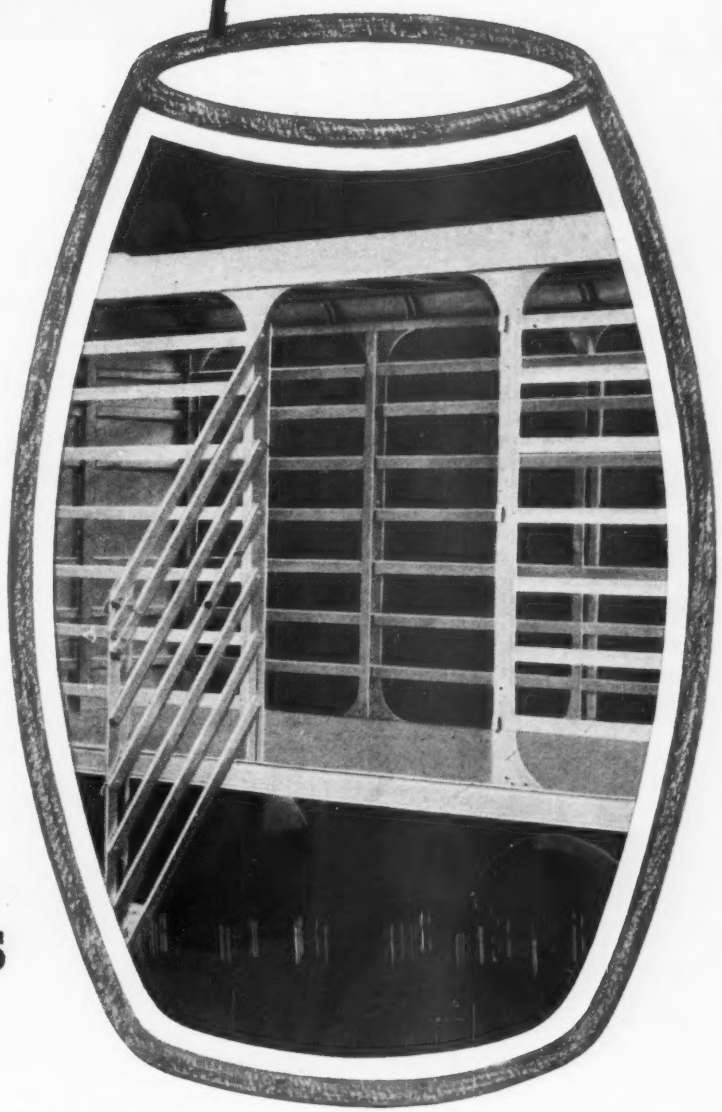
That will be the dray!

LOADING AND UNLOADING of beer casks in confined areas presents no difficulty to the Friary Brewery, of Guildford. The collapsible side and rear gates of this ingenious trailer-dray pivot on the uprights and will drop down into less than half the normal space.

Built by Locomotors Ltd. of Andover, using Birmetals light alloy sections and tubular side rails, the dray is easy to clean and popular with draymen.

This body is exceptionally light, weighing only 12 cwts., and yet it has a load capacity of 10 tons.

Do you know how Birmetals light alloy sheets and sections simplify bodywork construction, and how large a range of materials is available from stock?
Why not ask us for full information?



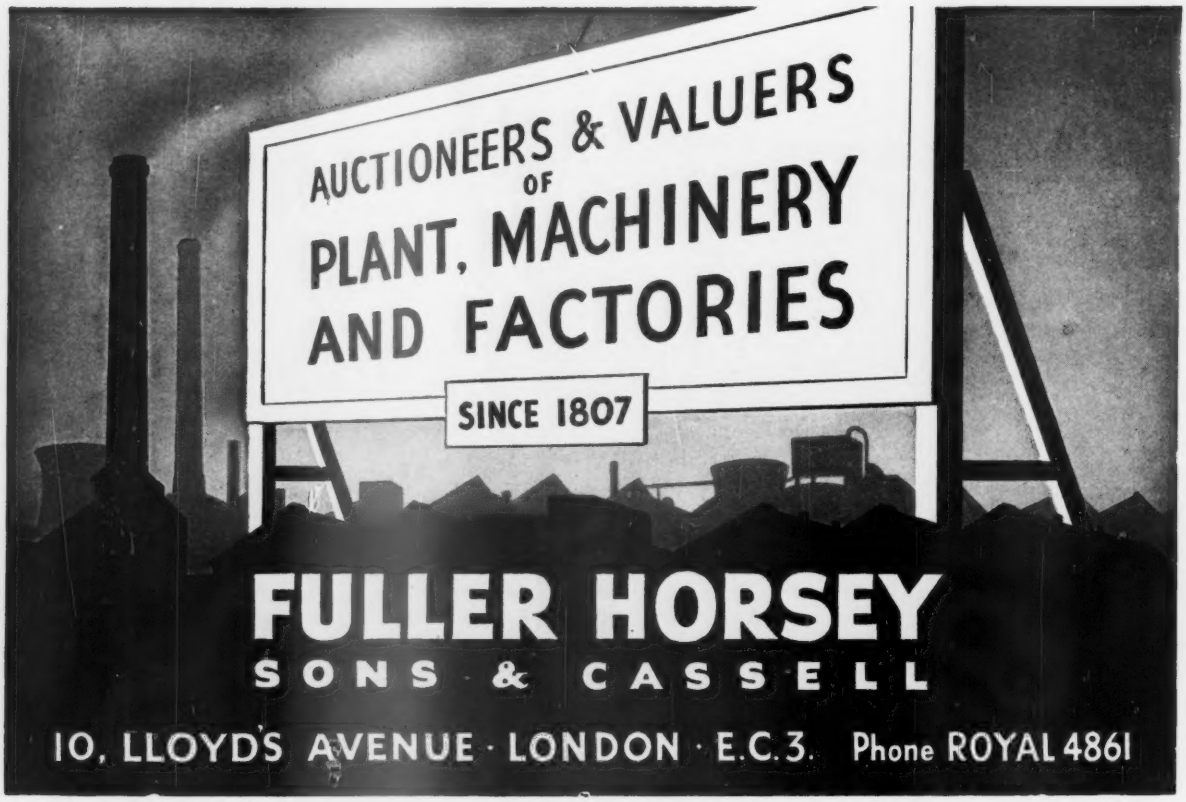
Birmetals

PIONEERS IN LIGHT ALLOYS

BIRMETALS LIMITED • BIRMINGHAM 32 • BIRMABRIGHT LIMITED

BH.80

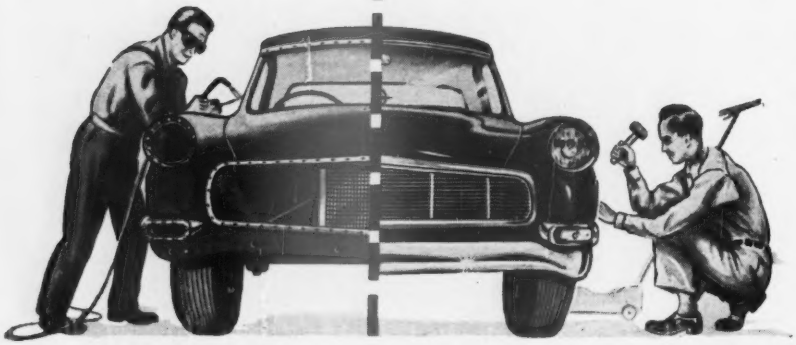
Engraved on 'Primag' magnesium alloy plate.



Rathbone

Factory or Workshop . . .

FRY'S for BODYBUILDING



FRY'S body solders are used by most British car manufacturers. Available in four grades, solders by FRY'S produce strong joints and economical patching requiring the minimum of hand-finishing.

ABBEY	Top quality tin-rich solder
BELFRY	High quality solder for general use
CLOISTER	An inexpensive solder—economical in use
CARBODY	For use where economy is essential

Please write for samples and prices

Export enquiries invited

FRY'S METAL FOUNDRIES LTD.
Tandem Works, Merton Abbey, London S.W.19
Telephone: MITcham 4023

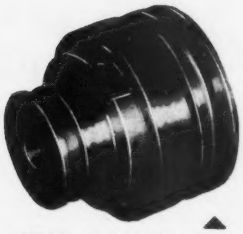
FRY'S
Body Solders

and at MANCHESTER · GLASGOW · BRISTOL · DUBLIN

MRP.52B

For the most efficient performance...

...IN POWER TRANSMISSION

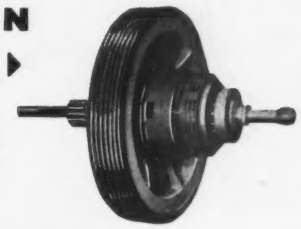


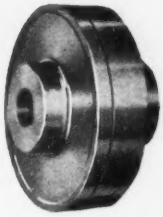
HIGH SPEED MULTIPLE DISC CLUTCHES

This design is particularly suitable for machine tool drives and for other machinery running at high speed. The clutch is very powerful for its size: it has a clean contour and it incorporates a compensating feature which eliminates frequent adjustment.

PNEUMATIC CLUTCH-BRAKE ASSEMBLIES

Suitable for presses, shearing machines, expanding and contracting machines, forging machines and all heavy duty drives of frequent operations.





FLEXIBLE COUPLINGS

This Elliptical Rubber Buffer Flexible Coupling is extremely efficient. The two shafts are free to move axially and the shape and flexibility of the Rubber Buffers ensure that even pressure is exerted by each Driving Lug. Suitable for either direction of rotation.

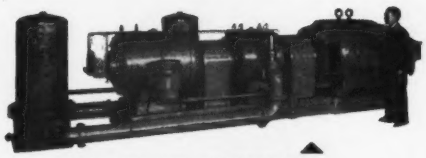
CLUTCH-BRAKE ASSEMBLIES

The illustration shows a pneumatic Clutch-brake Assembly supplied for a 500 ton Forging machine. Duty 1,100 h.p. at 42 r.p.m. frequency 3-4 strokes per minute.

DRY MULTIPLE DISC POWER TAKE-OFF CLUTCHES

Self contained Power Take-off assembly with 2 to 1 reduction gear.

...AND AIR/GAS HANDLING PLANT

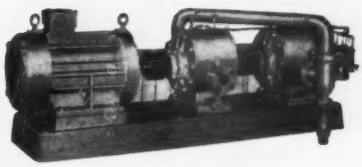


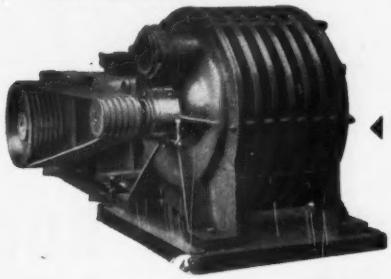
ROTARY AIR COMPRESSORS

Two Stage Rotary Compressors having a free air capacity of 1000 C.F.M. at 100 lb/sq. inch pressure. Full range of machines available up to 2070 C.F.M. displacement.

ROTARY VACUUM PUMPS

Two Stage Rotary Vacuum Pump. 290 C.F.M. displacement, 29.98 inches H.C. Full range of machines available up to 2070 C.F.M. displacement.





TURBO BLOWERS AND EXHAUSTERS

Range available up to 7½ lb/sq. inch pressure and 10 inches of Mercury Vacuum.

Whittaker Hall

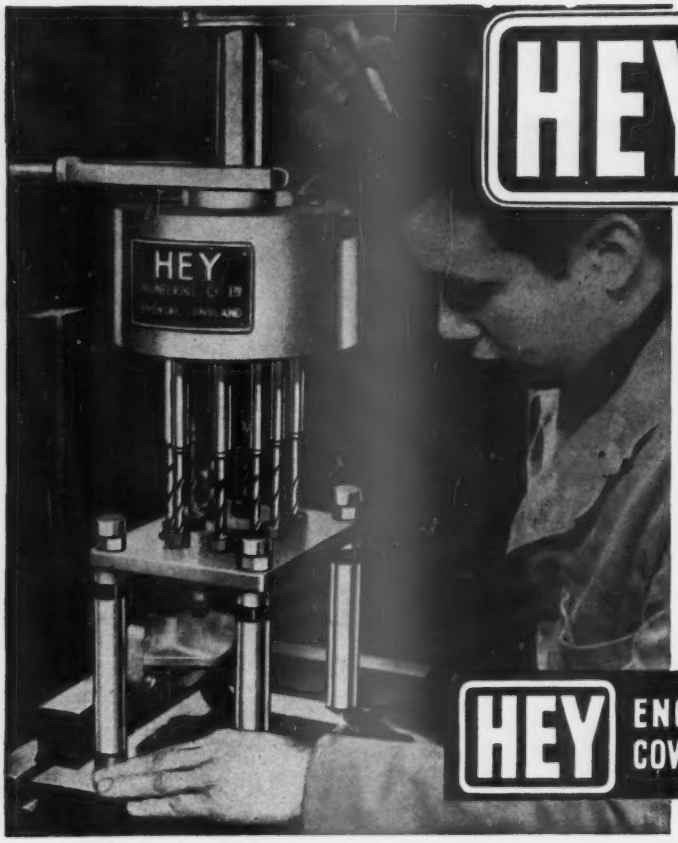
WHITTAKER HALL & CO. (1929) LIMITED

(Sole proprietors of R. S. Wittig & Co. (Compressors) Ltd.)

RADCLIFFE, LANCASHIRE

'Phone: Radcliffe 2421-2 'Grams: Clutch, Radcliffe, Manchester

London Office: 119, VICTORIA STREET, S.W.1 'Phone: Victoria 2612.



HEY

MULTIPLE DRILL HEADS

★ COMPACT IN DESIGN
★ FIXED OR ADJUSTABLE CENTRE DISTANCES

Hey Multiple Spindle Drill Heads convert Standard Drilling and Boring Machines to High Production Machines permitting drilling of all holes in a component simultaneously, with production rates equal to those obtainable on expensive special purpose machines.

Compact design reduces to a minimum, distance from drill head to machine spindle, whilst careful selection of material ensures an extremely efficient light weight head.

Heads are available with any number of spindles, covering a wide range of sizes

MAXIMUM PRODUCTION ON DRILLING, REAMING, TAPPING AND SPOT FACING OPERATIONS

HEY ENGINEERING CO. LTD.
COVENTRY 'PHONE: COVENTRY 88641

We also manufacture Rotary Cam and Profile Milling Machines, Short Thread Milling Machines, Gear Tooth Rounding Machines, Tapping Machines, End Facing and Centring Machines, Special Machine Tools for High Production.

Rainbow

essential to every manufacturer and user of plastics

BRITISH PLASTICS YEAR BOOK contains the equivalent of nine up-to-the-minute plastics reference books, giving quick access to vital information on firms, personalities, products, services and general and technical matters concerning every branch of the plastics industry. It is an indispensable aid to all who make, buy or sell plastics materials, machinery, products and services. Make sure of your copy TODAY—the edition is limited and sells out quickly.

NINE BOOKS IN ONE VOLUME

PATENTS, NEW COMPANIES AND STANDARDS FOR PLASTICS
MATERIALS
MANUFACTURED PRODUCTS
PLANT AND EQUIPMENT
NAMES AND ADDRESSES
WHO'S WHO
ASSOCIATIONS and FEDERATIONS
TECHNICAL and GENERAL DATA
QUICK-REFERENCE INDEXES

BRITISH PLASTICS YEAR BOOK 1957

every section is an indispensable volume in itself

Order your copy NOW . . . 42s net
by Post 43s 9d

Obtainable from your bookseller or direct from:-
ILIFFE & SONS LIMITED, DORSET HOUSE, STAMFORD STREET, LONDON S.E.1. WATerloo 3333

Take a tip from Timinium

For carrying coal a lorry needs to be strong and able to withstand more than its share of hard knocks. That is one reason why Timinium alloys were chosen here. Another, equally important, was their lightness which saves very considerably on deadweight and enables much heavier loads to be carried without any additional strain on springs, brakes or engine. In many cases the reduced bodyweight can also result in a lower rate of tax.

To any manufacturer concerned with the problem of higher performance from goods or passenger vehicles Timinium alloys may well provide a ready answer. Designers are freely invited to talk things over with our Development Department.

The body and chassis of this tip-lorry are among the standard assemblies supplied by Holmes (Preston) Ltd.

T I Aluminium Ltd

ONE OF THE LARGEST U.K. MANUFACTURERS OF SHEET, CORRUGATED SHEET, STRIP, CIRCLES, PLATE, EXTRUDED SECTIONS AND TUBES IN THE TIMINIUM RANGE OF ALUMINIUM AND ALUMINIUM ALLOYS

A TI COMPANY

Head Office: Redfern Road, Tyseley, Birmingham 11. Tel. Acocks Green 4211.

Offices in: LONDON, BIRMINGHAM, MANCHESTER, LEEDS, GLASGOW, BRISTOL, BELFAST AND DUBLIN

'O' RINGS

Full range of British standard sizes available

BONDED Seals

Steel and rubber bonded joint washers for pressures up to 10,000 lb. square inch

'SELOCS'

The multi-purpose washer that locks, seals and protects

Enquiries invited

DOWTY Seals

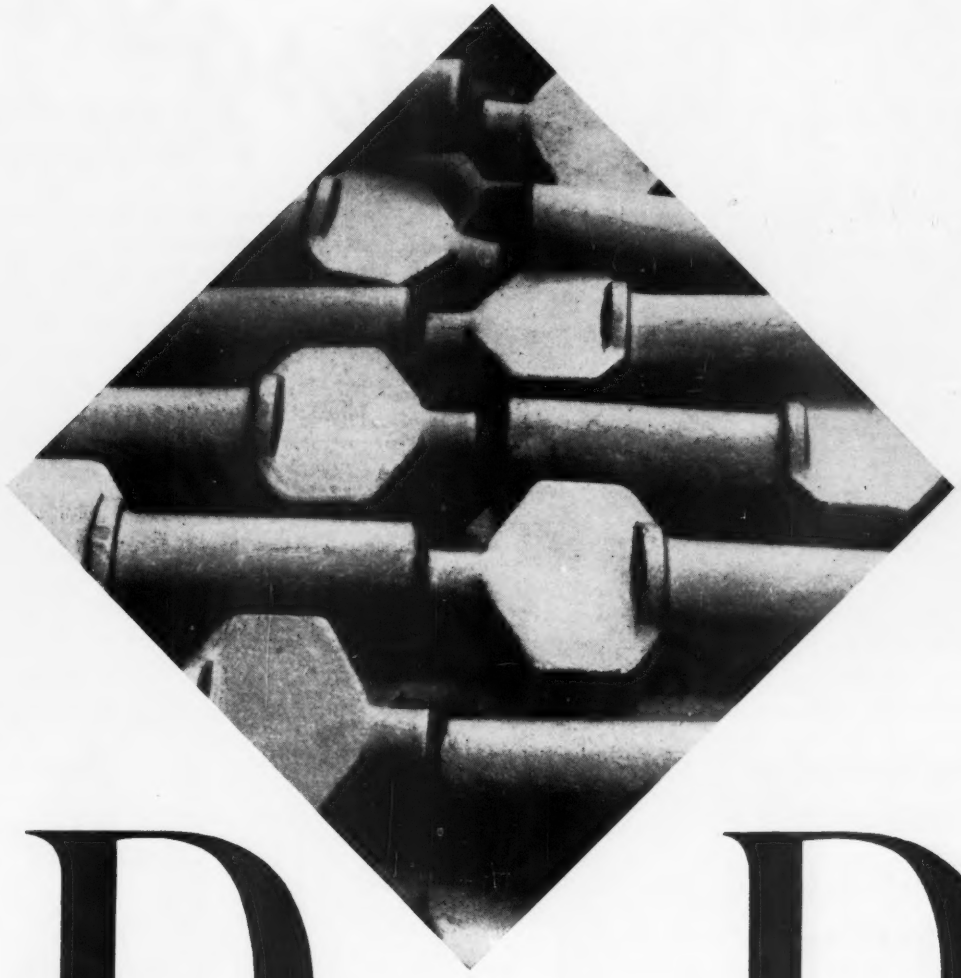
DOWTY SEALS LIMITED • ASHCHURCH • GLOS

Member of the DOWTY GROUP

Telephone Tewkesbury 2271

DONCASTERS for DROP FORGINGS

in large or small quantities

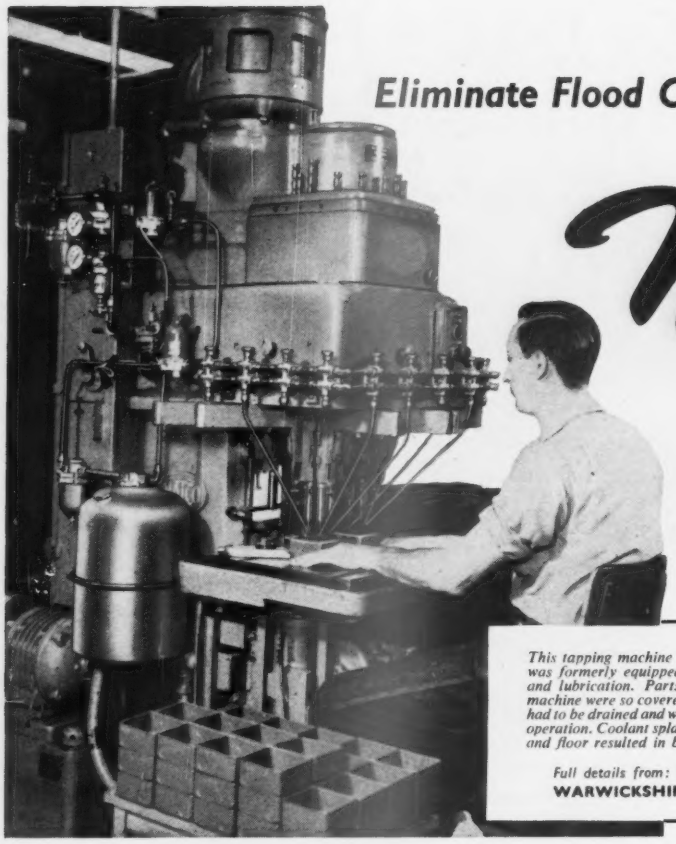


D D

DONCASTERS ◇
1778 D D

DANIEL DONCASTER & SONS LIMITED · SHEFFIELD

FORGINGS · DROP FORGINGS · HARDENED STEEL ROLLS · HEAT TREATMENT



Eliminate Flood Cooling? TRY THE

Norgren

SPRAY-LUBE & MISTCOOL systems

The Norgren Spray-Lube and Mistcool systems are a revolutionary development of the oil-fog system of lubrication. On a wide range of metal cutting and forming operations, they give cooling lubrication just where you need it—directly on the cutting area. Spray-Lube and Mistcool help to increase production and cut costs—write for illustrated literature.

This tapping machine uses up to 12 taps, was formerly equipped for flood cooling and lubrication. Parts coming from the machine were so covered with oil that they had to be drained and wiped before the next operation. Coolant splashing over operator and floor resulted in bad working conditions. After installing Spray-Lube, parts were no longer covered with oil, and the eliminating of draining and wiping increased production speed by as much as 30%. In addition, working conditions are cleaner and safer, and a substantial saving in cutting oil consumption is effected.

Full details from: **C. A. NORGREN LIMITED, SHIPSTON-ON-STOUR, WARWICKSHIRE.**
Telephone: Shipston-on-Stour 110 & 106

M-W.126

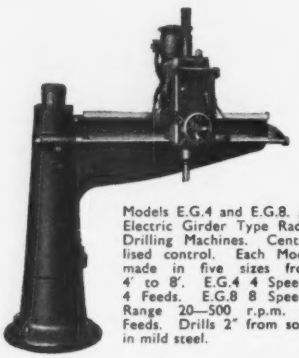
TOWN

drilling machines

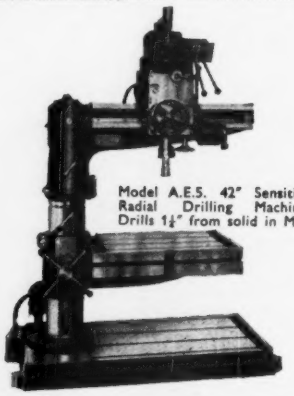
FREDK. TOWN & SONS LTD

HALIFAX · YORKSHIRE

Established 1903

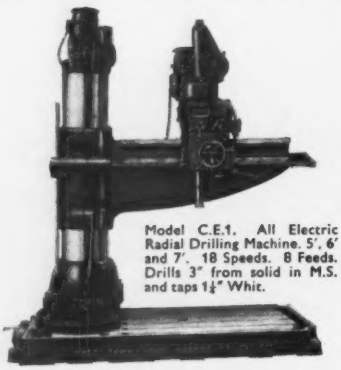


Models E.G.4 and E.G.8. All Electric Girder Type Radial Drilling Machines. Centralised control. Each Model made in five sizes from 4′ to 8′. E.G.4 4 Speeds. 4 Feeds. E.G.8 8 Speeds. Range 20—500 r.p.m. 4 Feeds. Drills 2″ from solid in mild steel.

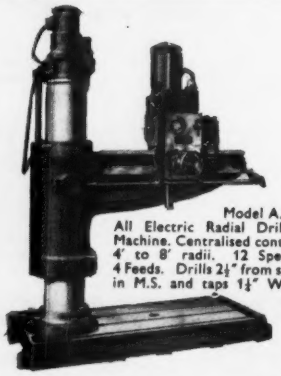


Model A.E.5. 42″ Sensitive Radial Drilling Machine. Drills 1¼″ from solid in M.S.

Model A.E.2. All Electric Heavy Duty Vertical Drilling Machine. Centralised control. Two sizes 36″ and 42″. 18 Speeds. 8 Feeds. Drills 3½″ from solid in mild steel.



Model C.E.1. All Electric Radial Drilling Machine. 5′, 6′ and 7′. 18 Speeds. 8 Feeds. Drills 3″ from solid in M.S. and taps 1¼″ Whit.



Model A.E.4. All Electric Radial Drilling Machine. Centralised control. 4′ to 8′ radii. 12 Speeds. 4 Feeds. Drills 2¼″ from solid in M.S. and taps 1¼″ Whit.

T.9

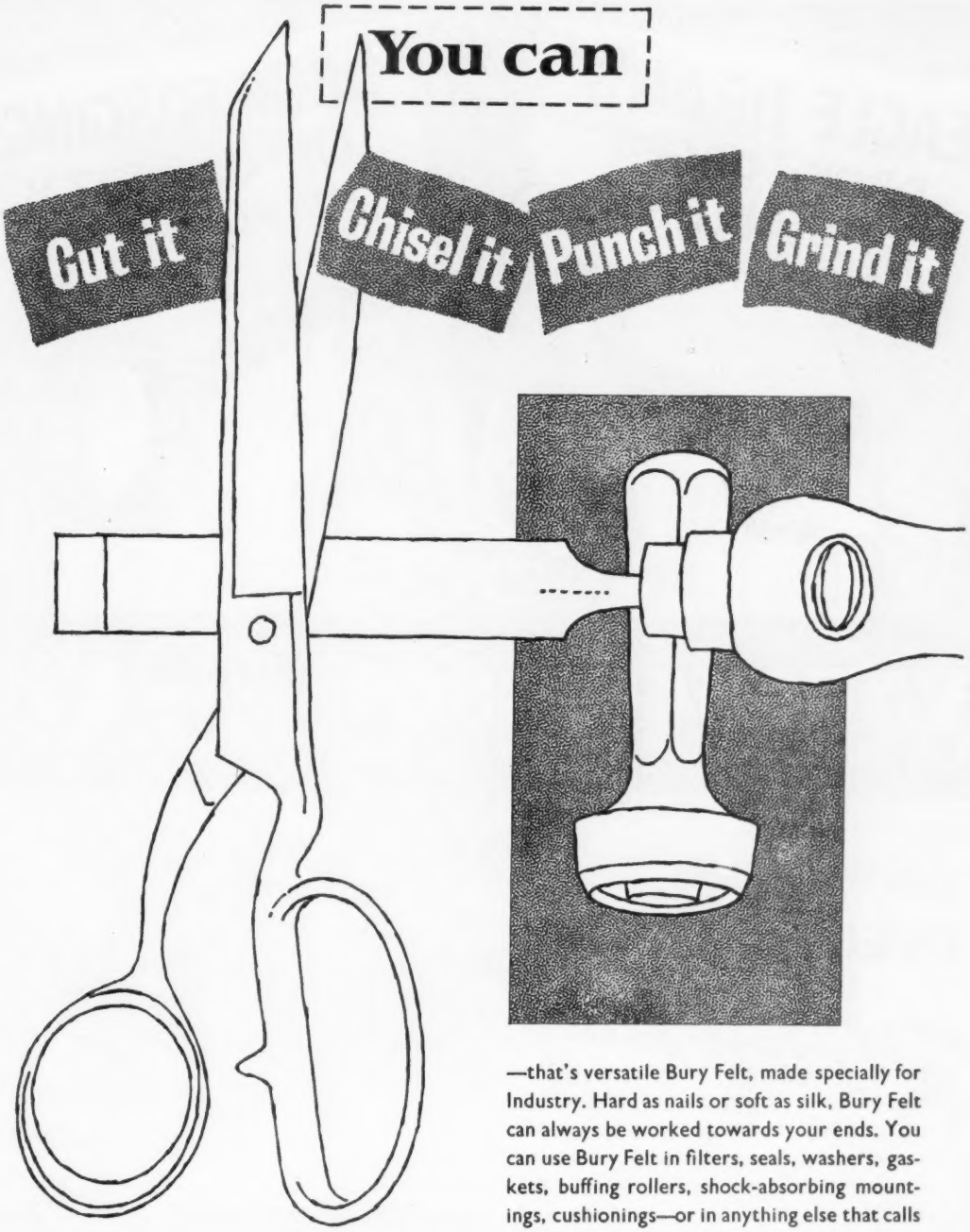
You can

Cut it

Chisel it

Punch it

Grind it



—that's versatile Bury Felt, made specially for Industry. Hard as nails or soft as silk, Bury Felt can always be worked towards your ends. You can use Bury Felt in filters, seals, washers, gaskets, buffing rollers, shock-absorbing mountings, cushionings—or in anything else that calls for felt.

Versatile stuff— BURY FELT

Send your enquiries to

BURY FELT MANUFACTURING COMPANY LIMITED, P.O. BOX 14, HUDCAR MILLS, BURY, LANCASHIRE · Phone: BURY 2262 (6 lines)

London Offices: 3 Snow Hill, E.C.1 · Phone: Central 4448

60

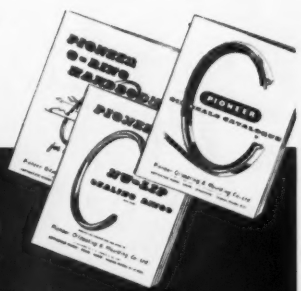
THE MOSS GEAR CO. LTD., CROWN WORKS, TYBURN, BIRMINGHAM 24. PHONE: ERDINGTON 1661-6. GRAMS: 'MOSGEAR, BIRMINGHAM'.

For the want of a seal
the oil was lost,
For the want of the oil
the bearing was lost,
For the want of the bearing
the machine was lost,
For the want of the machine
production was lost . . .

Pioneer Personal Oilsealing Service . . .

means factory trained men dealing with your problem on the spot, recommending the right seals for the job and making a personal inspection when they are in use. Solve your oil sealing problems with Pioneer.

WRITE NOW FOR COMPREHENSIVE CATALOGUES ON OIL SEALS, O-RINGS AND NU-LIP RINGS



PIONEER OILSEALING & MOULDING CO. LTD | A DIVISION OF J. H. FENNER & COMPANY LTD.

Factory and Head Office: Cottontree Works, Colne, Lancashire. Telephone: Wycoller 411|2|3

In production on the Bedford

TILGHMAN'S

MULTI-TABLE AIRLESS WHEELABRATOR

Two Multi-table Wheelabrator plants, each having four 48" tables, in production on Bedford components.
The machine in the foreground is dealing with Bedford finish-machined layshaft pinions, whilst the second machine is engaged on camshafts.

TILGHMAN'S LIMITED · Broadheath · Altrincham · Cheshire

LONDON OFFICE: 1, CHESTER STREET, S.W.1

AGENTS:
MIDLANDS: R. J. Richardson & Sons, Ltd., Commercial Street, BIRMINGHAM
SCOTLAND: Balbardie Ltd., 110, Hanover Street, EDINBURGH
227, Bath Street, GLASGOW, C.2
NORTHERN IRELAND: W. E. Stewart, 16 Sussex Place, BELFAST

W.43

In the words of Shakespeare:

"The will of man is by his reason sway'd"

"A Midsummer Night's Dream." Act II. Sc. II.

. . . . and wherever reason prevails the "Pop" Riveting System is the automatic choice for the solving of assembly problems.

Requiring only one side of the joint to be accessible to the operator, the "Pop" Riveting System is the fastest, simplest and most economical method available for assembly work where accessibility and avoidance of damage and distortion of the structure are of the utmost importance.

There is a "Pop" Rivet application in your assembly line—let us send you further details.

"POP" RIVETING
ONE OPERATOR OPERATION

Geo. **TUCKER EYELET** Co. Ltd.
Walsall Road · **BIRMINGHAM 22**
Telephone : BIRchfields 5024 (7 lines) Telegrams : EYELETS, BIRMINGHAM
Consultants & Tool Manufacturers :
AIRCRAFT MATERIALS LTD. Midland Road, London, N.W.1
"POP" is a regd. Trade Mark of Geo. Tucker Eyelet Co. Ltd.

THE MODERN SYSTEM OF RIVETING

Quality Products

HOUGHTO-SOLV "W"

Quick-acting

INDUSTRIAL FUEL OIL ADDITIVE

Houghto-Solv "W" enables you to burn all the Fuel Oil you buy and eliminates expensive cleaning jobs. Clean tanks, lines, strainers, nozzles and pumps ensure steady, efficient heating.

HOUGHTO-SOLV "W" DISSOLVES SLUDGE

makes it burnable

Research Service

Edgar Vaughan & Co. Ltd.

BIRMINGHAM 4 · ENGLAND

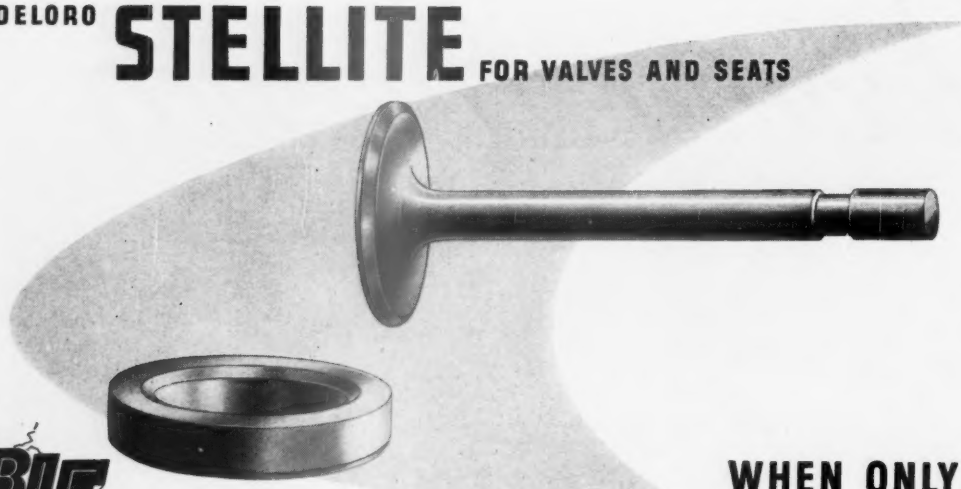
Works and depots at:

BIRMINGHAM · MANCHESTER
LIVERPOOL · SOUTHALL (Middx.)
GLASGOW · BRISTOL

THE CHOICE OF ROLLS ROYCE FOR 20 YEARS

ROLLS ROYCE

DELORO **STELLITE** FOR VALVES AND SEATS



BIF BIRMINGHAM 6-17 May 1957 We are exhibiting

Stand No. D. 402

WHEN ONLY THE BEST IS ACCEPTABLE

DELORO STELLITE LIMITED · HIGHLANDS ROAD · SHIRLEY · SOLIHULL · WARWICKSHIRE · ENGLAND
DIV. OF DELORO SMELTING & REFINING CO. LTD. · BELLEVILLE · ONTARIO · CANADA

Lower oil consumption smoother running with DUAFLEX Oil Control Rings

This model 'O' Bedford, operated by Pease Transport Limited (Carriers for Tate & Lyle Limited), was fitted with Duaflex Rings when oil consumption was 1 pint in 88 miles. After fitting, the oil consumption fell to 1 pint in 405 miles and 56,000 miles were completed on this set of rings before oil consumption again rose to a prohibitive figure. This efficient Transport Organisation has equipped many other vehicles of different makes with Wellworthy Duaflex Rings and it is well satisfied with the general improvement in engine efficiency.

Duaflex Rings restore power and efficiency

More and more fleet owners are fitting Duaflex Rings in worn engines using an excessive amount of oil but not yet due for a major overhaul. Self-adjusting Duaflex Rings take up irregularities in the bore and form a gas-tight seal between pistons and cylinder walls, thus reducing oil consumption and restoring lost compression.

How Duaflex Rings work

1 The vertical sealing spring keeps the rails firmly in the ring groove, forming a perfect seal.

2 The expander maintains an even outward pressure on cylinder walls.

3 The rails 'wipe' oil from cylinder walls, avoid scraping and wear.

For best results fit Wellworthy Pistons with Matched Sets of Wellworthy Rings at the same time as fitting Duaflex Oil Control Rings.

WELLWORTHY

DUAFLEX

OIL CONTROL RINGS

'The Choice of the Expert'

REDUCE OIL CONSUMPTION
INCREASE COMPRESSION · DEFER RE-BORES

Write for leaflet A.2/4 to :—
WELLWORTHY LIMITED · LYMINGTON · HANTS

Sentinel UNIT MACHINES

FAST VERSATILE ECONOMICAL

SENTINEL UNIT MACHINES incorporating the Renault-France system electro-mechanical heads.
Built for—Drilling, Boring, Facing and Chamfering. 8 different types of Manifolds (*see inset*). Two manifolds are loaded, pneumatically located and clamped.
Press a button to start—and in less than 30 seconds the machining cycle is completed!

AN EXAMPLE OF FLEXIBILITY

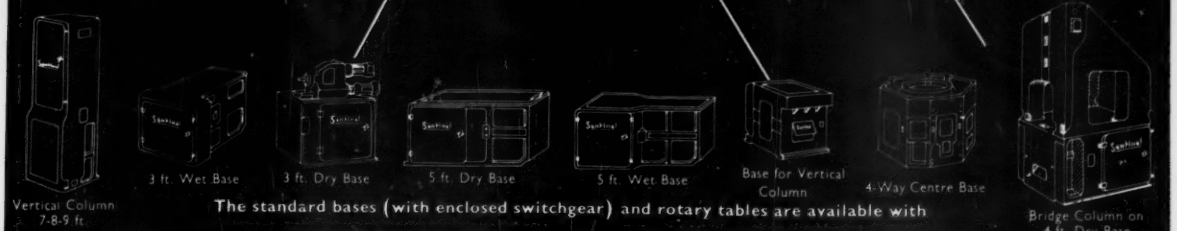
This Unit Machine comprises a

3 ft. Dry Base, and an EMH 10 with Boring, Facing and Chamfering Tools.

3 way Centre Base.

4 ft. Dry Base, and an EMH 10 with Boring, Facing and Chamfering Tools.

Bridge Column, and an EMH 20 with a 12 multi-spindle head.


Vertical Column 7-8-9 ft.
3 ft. Wet Base
3 ft. Dry Base
5 ft. Dry Base
5 ft. Wet Base
Base for Vertical Column
4-Way Centre Base
Bridge Column on 4 ft. Dry Base

The standard bases (with enclosed switchgear) and rotary tables are available with machined mating faces for assembly into any combination of units.

SENTINEL (SHREWSBURY) LTD SHREWSBURY ENGLAND

Telephone: SHREWSBURY 2011 Telegrams: "SENTNOLL SHREWSBURY" London Office: 60 BUCKINGHAM PALACE ROAD LONDON S.W.1 Telephone: SLOANE 0098

P4108

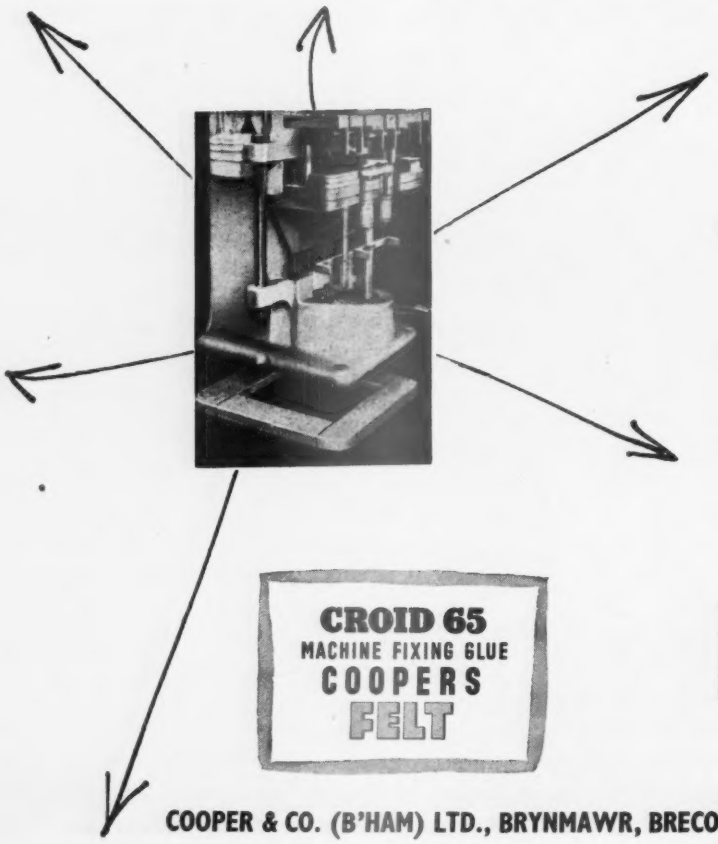
.... trouble is, he's so keen on G.G.L that he keeps talking about their wonderful service even when you want to concentrate on something else. I quite agree that there's nobody like G.G.L. for Capstan Work, Pressings and Automatic Productions.... oh!
G·G·L

For quick service at the right price get in touch with :

GRIFFITHS, GILBART LLOYD & CO. LTD.

EMPIRE WORKS, PARK ROAD, BIRMINGHAM, 18. Telephone: NORthern 6221.

CAPSTAN AND AUTOMATIC WORK AND SHEET METAL PRESSINGS, IN ANY METAL, ANY FINISH, ANY QUANTITY



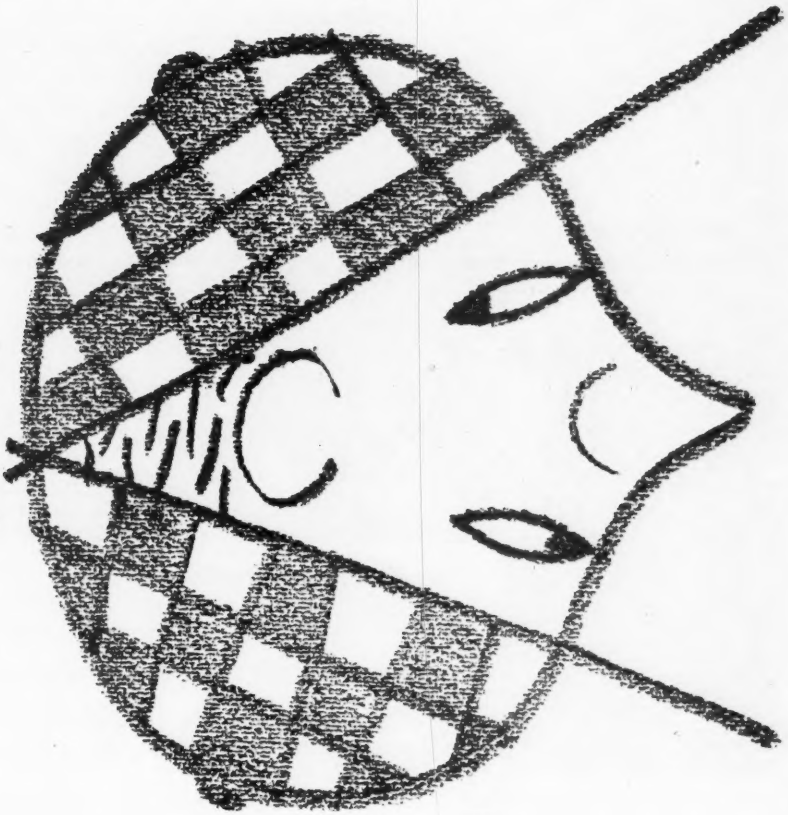
PUT IT THERE . . . . . .
OR THERE . . . . .
OR THERE . . . . .

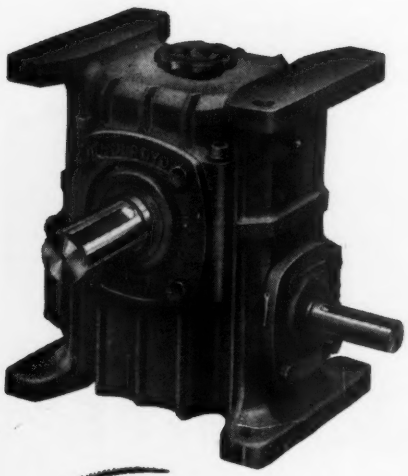
Imagine your machines stuck down on a felt base which can absorb over 80% of vertical vibration, which has a holding power of 50 lb. to the square inch, which does away with bolts, grouting, damaged floors. Then imagine deciding to change your layout when the workers have left one evening and having all the machines ready for action again in the morning. That's what Croid-Cooper can do for you. Send for details to-day.

SEE US AT STAND C.104
FACTORY EQUIPMENT EXHIBITION, EARLS COURT. April 29-May 4, 1957.

COOPER & CO. (B'HAM) LTD., BRYNMAWR, BRECONSHIRE · TELEPHONE: BRYNMAWR 312

GOOD EACH WAY





You can mount the VERSO *underdriven* —right way up. You can mount the VERSO *overdriven*—still right way up. It works just as well either way. This *new* Holroyd speed reducer has solid feet top and bottom. It's two units in one—underdriven or overdriven as you please. There are other ways of mounting it as well. It will run continuously under the heaviest loads and the toughest conditions. The VERSO is available *now* from stock. Do you want to know more about it? We'll be glad to send you a leaflet giving all the technical details.

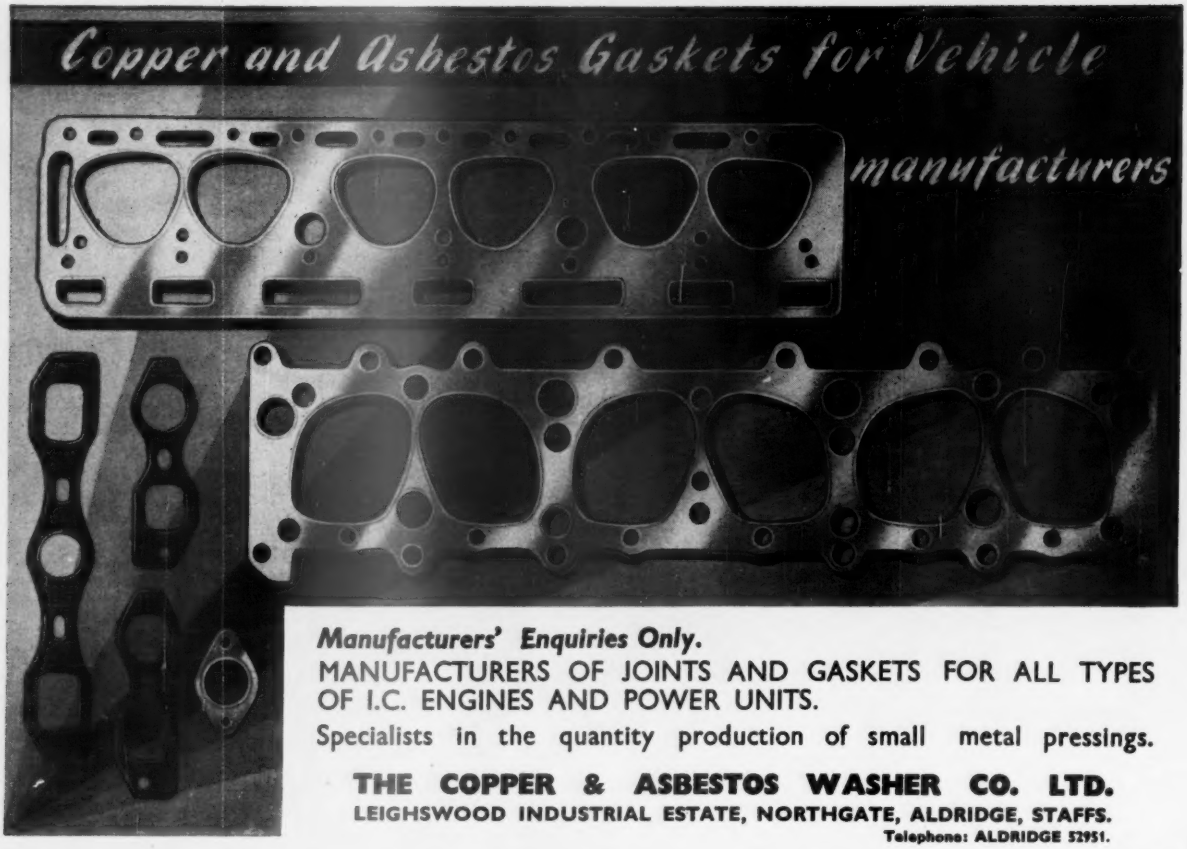
The VERSO is a 2½" centre distance speed reducer designed for heavy duty industrial work. Standard ratios are from 5/1 to 70/1, and depending on the ratio 3½ h.p. can be transmitted. The VERSO is suitable for input speeds up to 3,000 r.p.m. The worm-wheel is made from centrifugally cast Holfos Bronze and the worm from nickel case hardening steel.

The Verso unit can be delivered from stock with any standard ratio from 5/1 to 70/1

THE VERSO WORKS **BOTH** WAYS

JOHN HOLROYD & **COMPANY LIMITED** · MILNROW · LANCS · TELEPHONE: MILNROW 55322

CRCV3



Manufacturers' Enquiries Only.

MANUFACTURERS OF JOINTS AND GASKETS FOR ALL TYPES OF I.C. ENGINES AND POWER UNITS.

Specialists in the quantity production of small metal pressings.

THE COPPER & ASBESTOS WASHER CO. LTD.

LEIGHSWOOD INDUSTRIAL ESTATE, NORTHGATE, ALDRIDGE, STAFFS.

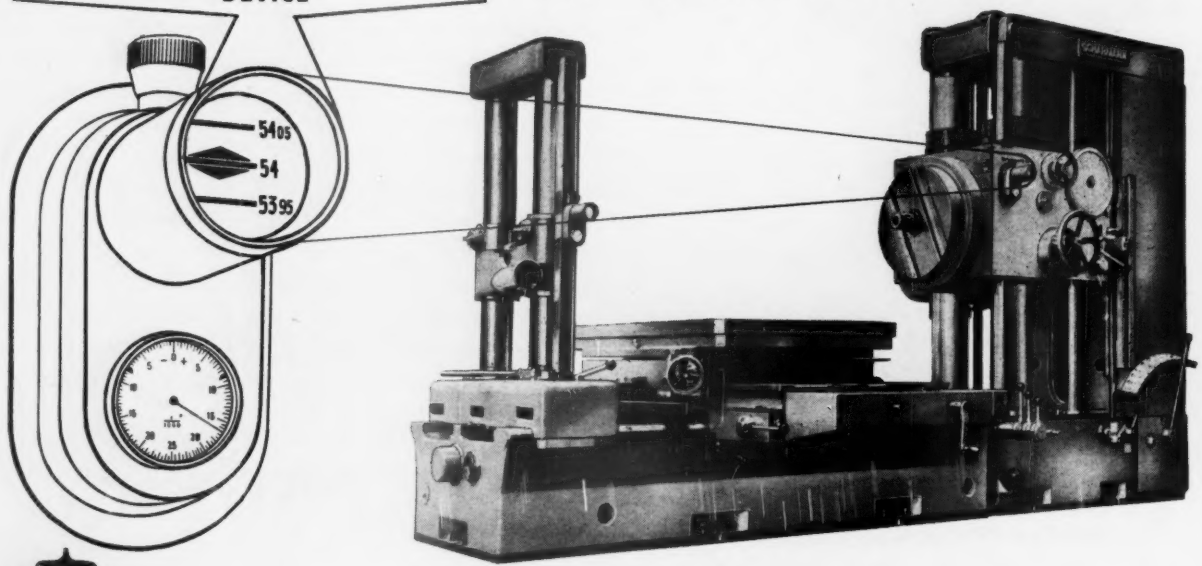
Telephone: ALDRIDGE 52951.

SCHARMANN

MODEL FB85 PRECISION AND BORING MACHINE

FITTED WITH OPTICAL MEASURING DEVICE

Model FB 85, having a 3¼" diameter boring spindle, can be fitted with optical measuring equipment; precision engraved glass scales enable direct positional readings to be made to the accuracy of 0·0004" or less.

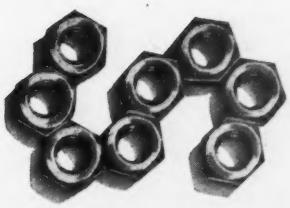


CHARLES **CHURCHILL** & CO LIMITED

COVENTRY ROAD SOUTH YARDLEY BIRMINGHAM 25

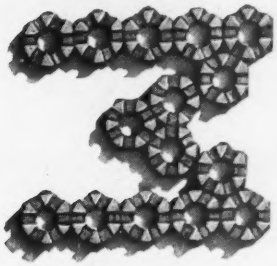
BRANCHES LONDON GLASGOW NEWCASTLE MANCHESTER

FF

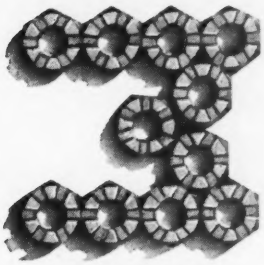


COLD FORMED
DOUBLE CHAMFERED
STEEL NUTS

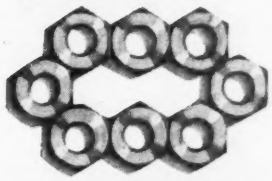
FULL NUTS



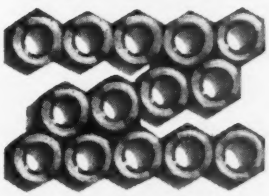
SLOTTED NUTS



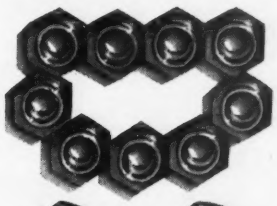
ROUND TOP
CASTLE NUTS



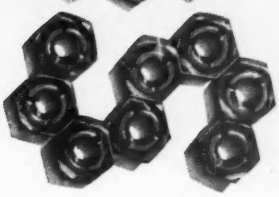
THIN LOCK NUTS



SPECIAL NUTS



HANK RIVET NUTS



COLD FORMED
WELDNUTS

A BIG NAME IN NUTS!

We're not going to *say* we make
the best nuts in the world (though
that doesn't stop us thinking so,
does it?) but we do suggest that
when you're buying Bar Turned
or Cold Formed Nuts it's worth remembering
our name. We manufacture large
quantities in a wide range of sizes,
steels and finishes—and if you want
a special nut or turned part
for a special job, we can supply it.

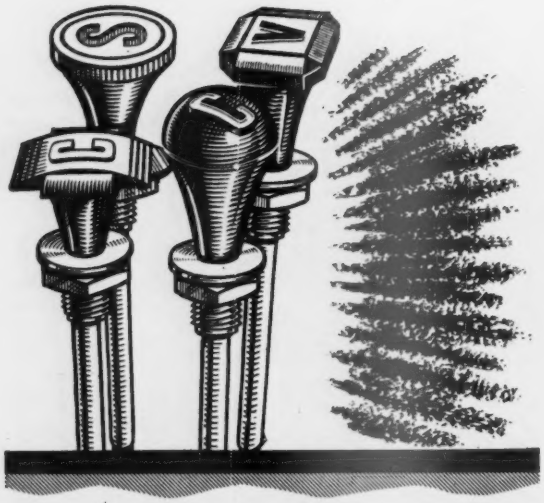
SIMMONDS
AEROCESSORIES
LIMITED

TREFOREST : PONTYPRIDD : GLAMORGAN

Branches: London, Birmingham, Manchester,
Glasgow, Stockholm, Copenhagen, Ballarat,
Sydney, Johannesburg, Amsterdam,
Milan and New York

FC A MEMBER OF THE FIRTH CLEVELAND GROUP

CRC 31N



Remote Control

for

THROTTLE
STARTER
BONNET
& CHOKE

Gill's Remote Control Cables are known the world over for long life and dependability. They are made from top-quality steel and are guaranteed rustproof.

GILL'S

CABLES LTD

PACKINGTON HALL WORKS, LICHFIELD, STAFFORDSHIRE

Telephone: Whittington 284 & 285.
Telegrams "Remote," Lichfield.

A complete Gill's Control Unit has immense strength and under normal working conditions there is never any danger of the inner control member of the cable section pulling out from the steel insert of the knob itself.

Wire

THREAD INSERTS

MAKE STRONGER THREADS UNDER ANY CONDITIONS IN ANY MATERIAL WHETHER FOR NEW DESIGNS OR SALVAGE

HARD TOUGH THREADS IN SOFT METALS

NEW THREADS FOR OLD

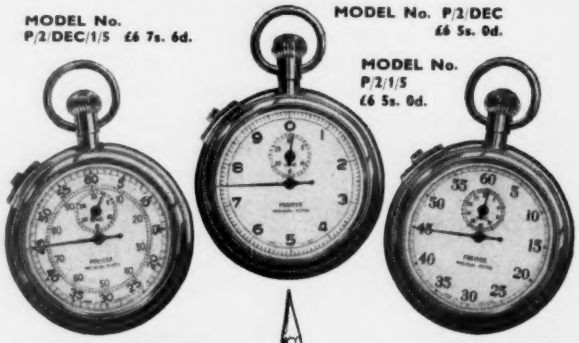
CROSS MANUFACTURING CO. (1938) LTD.

Telephone: COMBE DOWN 2355/6
BATH, SOMERSET
Telegrams: CIRCLE, BATH
Sales Enquiries: COMBE DOWN 2575

MODEL No. P/2/DEC/1/5 £6 7s. 6d.

MODEL No. P/2/DEC £6 5s. 0d.

MODEL No. P/2/1/5 £6 5s. 0d.



A NEW STANDARD IN BRITISH MADE

The very competitive prices of these Stop-Watches have been achieved without any lowering of the high standard associated with the name PRESTEX. Tested within very fine accuracy limits, especially made to satisfy the exacting demands of Science and Industry.

—A NEW VALUE STOP-WATCHES

PRESTEX Timers have a 7-jewelled pallet movement, and are made from the finest materials. The precision duplication of parts means speedy and efficient repairs when needed, although with normal care and usage these watches will give durable and dependable service.

Prestons *INDUSTRY'S LARGEST—*

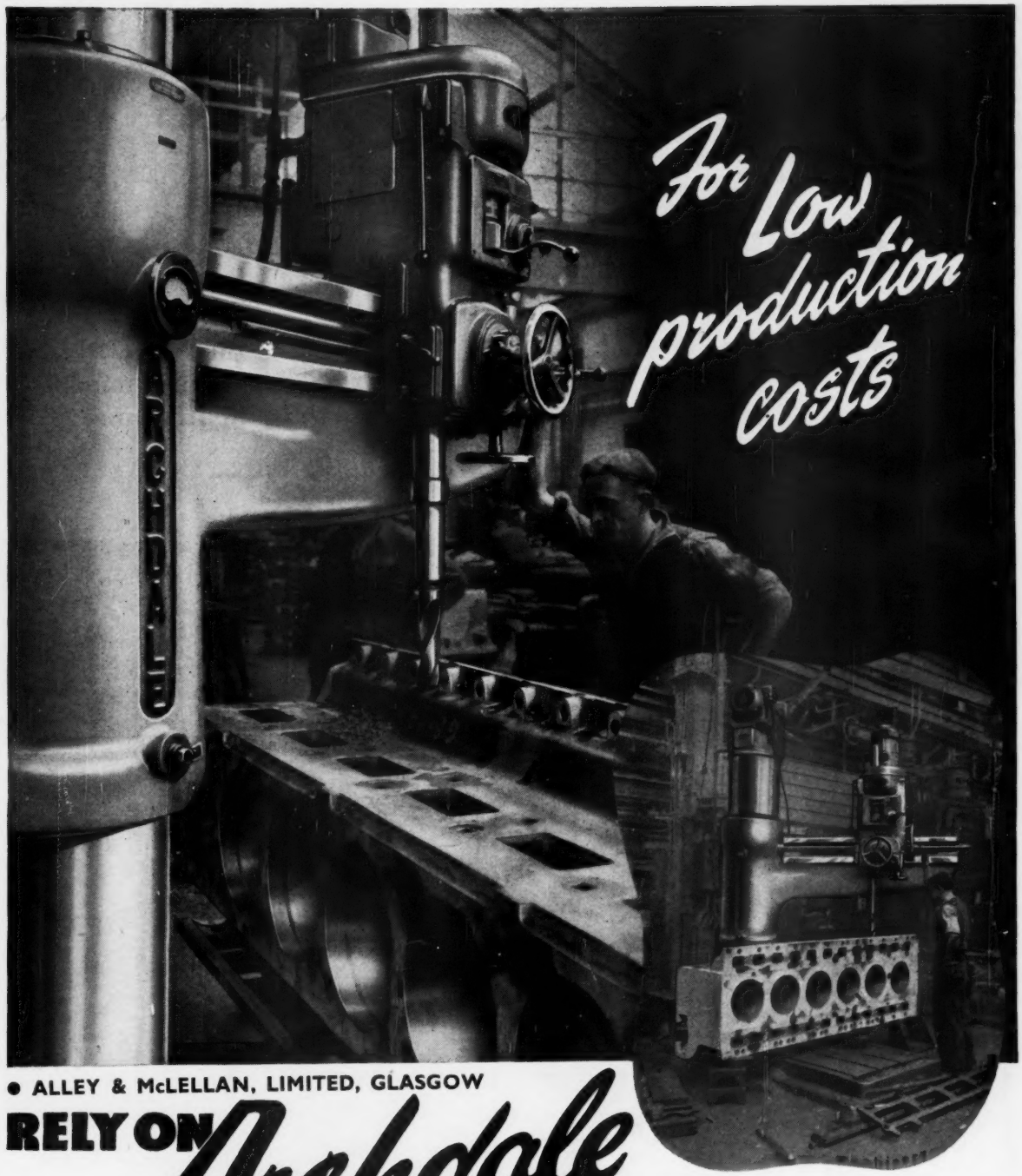
PRESTEX *Precision-Tested* STOP-WATCH

Limited *STOP-WATCH SUPPLIERS*

PRESTEX Precision-Tested Stop-Watches are available only from Prestons Ltd.

Write for our illustrated leaflet giving full particulars to this address . . .

PRESTONS LTD., PRESTEX STOP-WATCH DIV., BOLTON, LANCS.



• ALLEY & McLELLAN, LIMITED, GLASGOW

RELY ON Archdale

MEDIUM DUTY HIGH SPEED RADIALS

The many outstanding features of this 6 ft. radius medium duty high speed radial are fully exploited in this well-equipped Glasgow workshop. Typical work includes gas engine crankcases, in which over 300 holes are drilled, ranging from ¼" to 2". Models are available with 4 ft., 6 ft. and 7 ft. spindle radius.

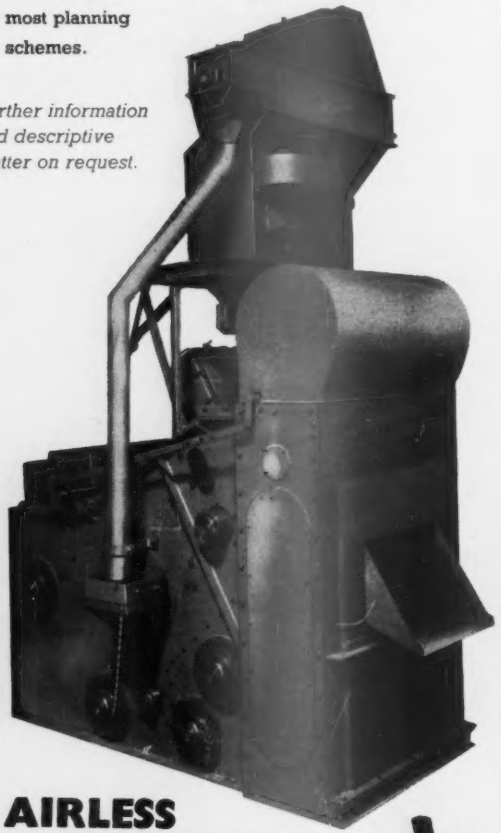
JAMES ARCHDALE & CO. LTD., LEDSAM STREET, BIRMINGHAM 16

SOLE AGENTS: ALFRED HERBERT LTD., COVENTRY

The CENTRIBLAST Automat

inserted in your production line will produce cleaned parts automatically, either in batches or as single units and its automatic load measure together with auto feed and discharge enable this equipment to be adopted in most planning schemes.

Further information and descriptive matter on request.



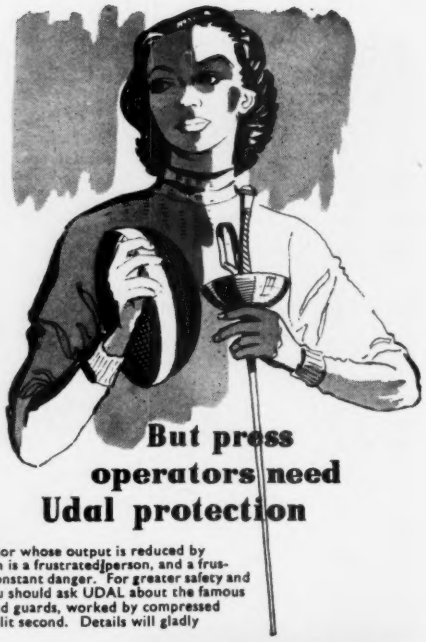
AIRLESS CONTINUOUS BLAST CLEANING MACHINE

SPENCER & HALSTEAD LTD.

BRIDGE WORKS · OSSETT · YORKSHIRE

TEL OSSETT 821-4 GRAMS SPENSTEAD

P4875



But press operators need Udal protection

A piece-work operator whose output is reduced by slow guard operation is a frustrated person, and a frustrated person is in constant danger. For greater safety and more production you should ask UDAL about the famous 'Fastrip' synchronized guards, worked by compressed air and timed to a split second. Details will gladly be sent on request.

J. P. UDAL LIMITED

INTERLOCK WORKS

COURT ROAD · BIRMINGHAM 12

Telephone : CALthorpe 3114

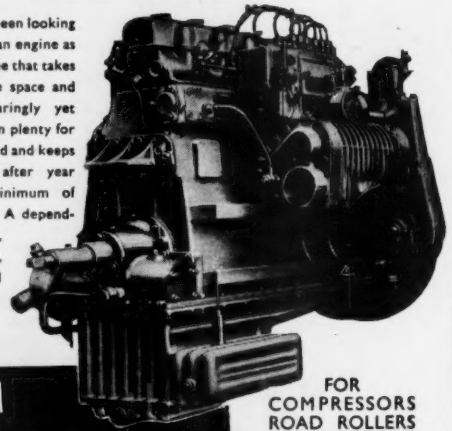
Udal PRESS GUARDS

HERE'S THE

Reliability

INDUSTRY DEMANDS

Industry has been looking for just such an engine as this—an engine that takes up very little space and uses fuel sparingly yet gives power in plenty for the job on hand and keeps going year after year with the minimum of maintenance. A dependable, versatile, hard working, economical engine.



Foden FD

4-, 6 & 8 - 12 CYLINDER 2 STROKE OIL ENGINES 50/240 B.H.P.

FOR COMPRESSORS ROAD ROLLERS RAIL SHUNTERS STATIONARY ENGINES

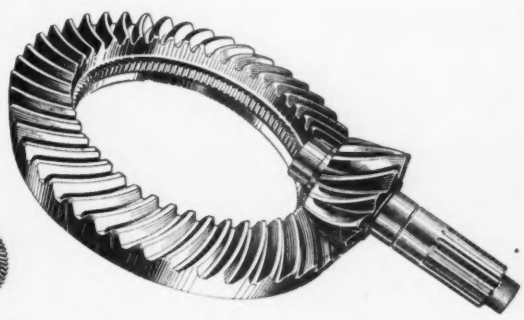
Send for details to—

ENGINE DIVISION FODENS LIMITED SANDBACH · CHESHIRE

Champions of their weight & class

The advantages of spiral bevel and hypoid gears are well established for right-angle drives. The design and manufacture of gears of this class are essentially matters for the specialist. E.N.V. therefore offer the services of experienced gear engineers on design problems plus comprehensive manufacturing resources to designers in connection with projects for which right-angle drives are needed. *Designers are invited to communicate, at the project stage, with the Technical Department.*

The right angle on gears



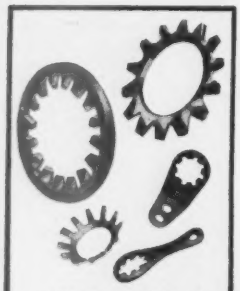
ENV FOR GEARS

E.N.V. ENGINEERING COMPANY LIMITED
Hythe Road, Willesden, London, N.W.10
Telephone: LADbroke 3622

AP60

WHY THE TWISTED TEETH?

Because every tooth on a 'Shakeproof' washer acts as a strut, preventing the screw or nut backing off. Every tapered, twisted tooth creates powerful spring tension between work surfaces, tension that ensures the lock is secure, tight. The sharp edges of each tooth anchor firmly, without milling. The greater the vibration — the stronger the lock. You can't find a more powerful lock than 'Shakeproof' Lock Washers, available in a wide range of sizes and types.



'Shakeproof' lock washers are available in tempered & hardened high carbon spring steel, or phosphor bronze.

A.I.D. APPROVED

"SHAKEPROOF"

REG. TRADE MARK Nos. B611535

LOCK WASHERS AND LOCKING TERMINALS

British Patents Nos. 406556 — 518146

BARBER & COLMAN LTD
MARSLAND RD · BROOKLANDS · MANCHESTER
TELEPHONE: SALE 2277 (4 LINES)
TELEGRAMS: "BARCOL" SALE

SHAKEPROOF PRODUCTS

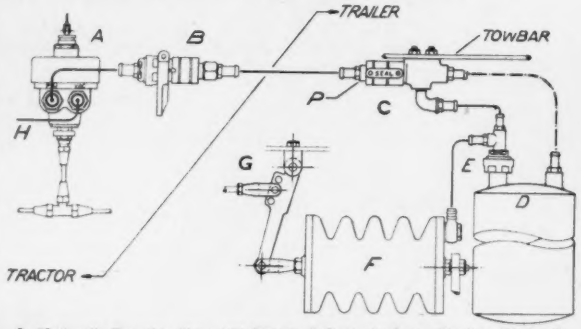
Dealers and Factors enquiries to the following appointed "SHAKEPROOF" stockists:

George Boyd & Co. Ltd. 229 Buchanan Street, Glasgow C.1.
Brown Bros. Ltd. (all Branches)
Wm. Galloway & Co. Ltd. Blaydon-on-Tyne.
F. Miller & Co. (London) Ltd. Rectory Road, Acton, London W.3.
Nettlefold & Moser Ltd. (all Branches)
Nobby Distributors Ltd. 438 Harrow Road, London W.9.
Wordrew Ltd. 173 Princess Street, Manchester, 1.

SB4

F&J

NEW SINGLE LINE PROGRESSIVE BREAKAWAY SYSTEM



A. Hydraulic Reaction Valve LV 207 Dual Control, shown fitted to Hydraulic Pipe Line on Tractor.
B. "C" type Coupling with Auto. Shut-off Valve, attached to rear of Tractor.
C. Breakaway Valve SBS. 256 (or SBS. 257) attached to Tow Bar of Trailer.
D. Vacuum Tank on Trailer.
E. Non-return Valve.
F. Power Unit on Trailer operating linkage **G** to Trailer Brakes.
H. Hose connecting LV 207 to source of Vacuum Hose connections shown as solid lines are those used in normal operation of Brakes. The Hose shown in broken line connects the Vacuum Tank to the Power Unit when Valve "C" is operated in emergency.
P. Safety Seal.

Existing Trailer can be converted by adding "C," "D" and "E."

FEENY & JOHNSON LTD

134-136, Ealing Road, Wembley, Middlesex
Tel: WEMbley 4801 & 4802 *Grams:* Feejohn, Wembley

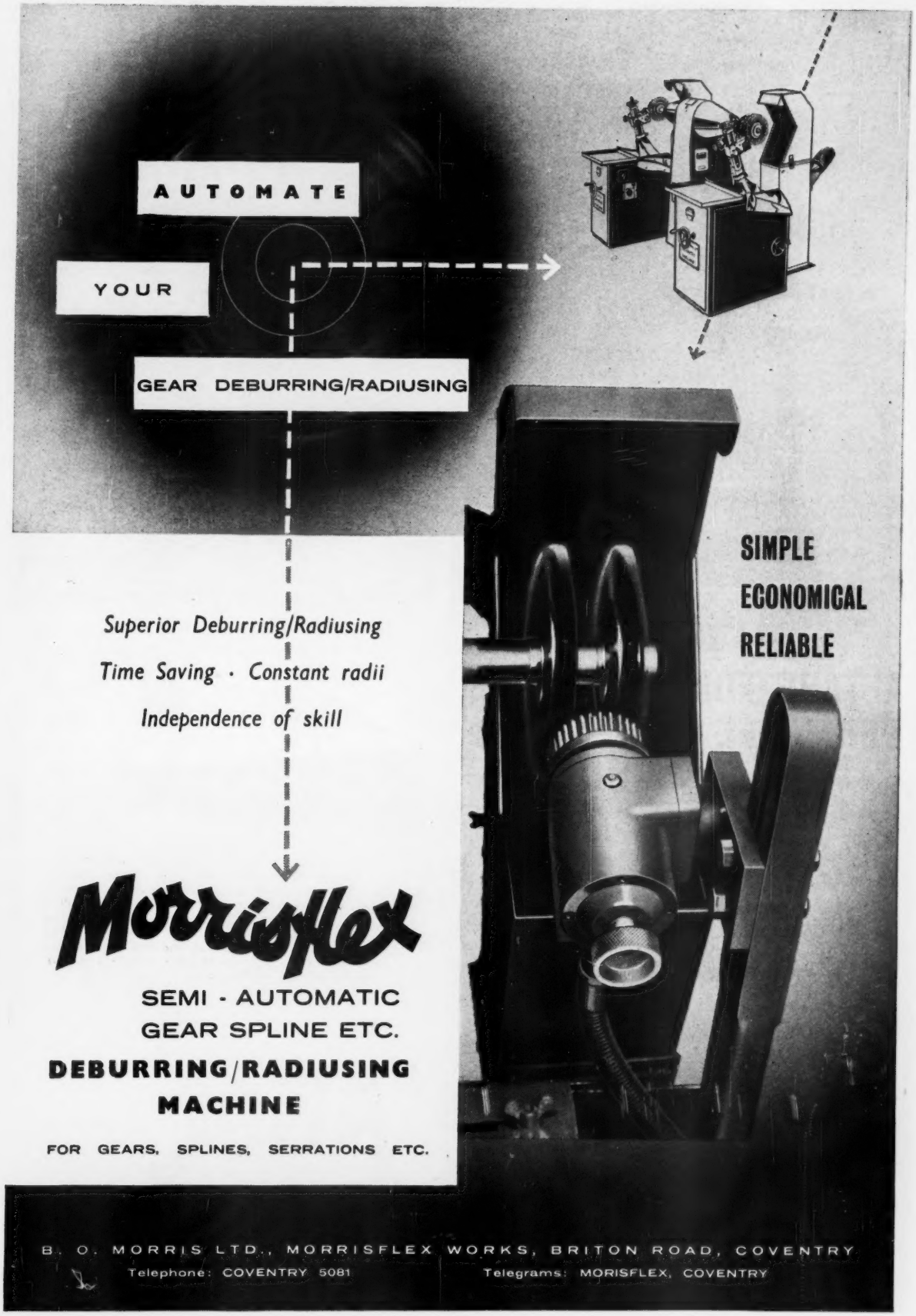
DHB/2902A

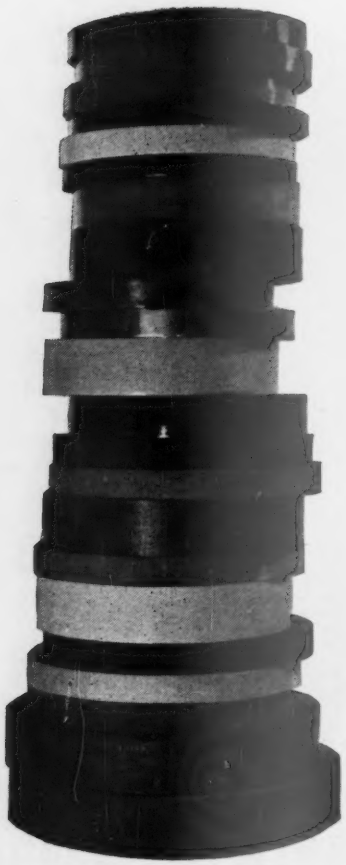
Good! a MITRE Drop Forging

We invite you to send for our sales folder which explains why MITRE precision Drop Forgings help to step up quality and production and reduce costs.

A. J. VAUGHAN & CO (MITRE WORKS) LTD

WOLVERHAMPTON ROAD WILLENHALL, Staffs. Phone 486/7


AUTOMATE
YOUR
GEAR DEBURRING/RADIUSING
Superior Deburring/Radiusing
Time Saving · Constant radii
Independence of skill
SIMPLE
ECONOMICAL
RELIABLE
Morrisflex
SEMI - AUTOMATIC
GEAR SPLINE ETC.
DEBURRING/RADIUSING
MACHINE
FOR GEARS, SPLINES, SERRATIONS ETC.
B. O. MORRIS LTD., MORRISFLEX WORKS, BRITON ROAD, COVENTRY
Telephone: COVENTRY 5081
Telegrams: MORISFLEX, COVENTRY



A TAPE FOR EVERY USE

PERMACEL SELF-ADHESIVE

TRADE MARK

Cellulose Tape
P.V.C. (Unplasticised) Tape
Cloth Sealing Tape
Cloth Masking Tape
Paper Masking Tape
Waterproof Cloth Tape
Super Strapping Tape

For more information about Permacel Tapes and Dispensers write for a free copy of our Permacel Brochure. It contains over 400 ways in which Permacel has been used to save time and money in Packing and Production.

PERMACEL
TRADE MARK

INDUSTRIAL MASKING TAPES
INDUSTRIAL DIVISIONAL Dept. A.E.

Johnson & Johnson (GT. BRITAIN) LTD., SLOUGH, BUCKS.

FACTORY EQUIPMENT EXHIBITION
EARLS COURT, April 29 — May 4, **STAND H20**

CALIBRATED JETS

Amal Limited make jet-calibrating machines for checking carburetter petrol jets to conform to British Standard No. 720 of 1948. Amal Limited are equipped to manufacture and calibrate jets from .005" to .5" dia. — all of which discharge a specified flow to within close limits under specified conditions. 'Amal' calibrated jets find many applications for metering the flow of other non-viscous liquids, and also of gases such as town gas, butane, propane, methane, etc.

AMAL

Service to the Motor and other Industries

AMAL LTD., WITTON, BIRMINGHAM, 6

A/127

GLOUCESTER

malleable & grey iron castings

TOUGH AND RIGID YET EASY TO MACHINE

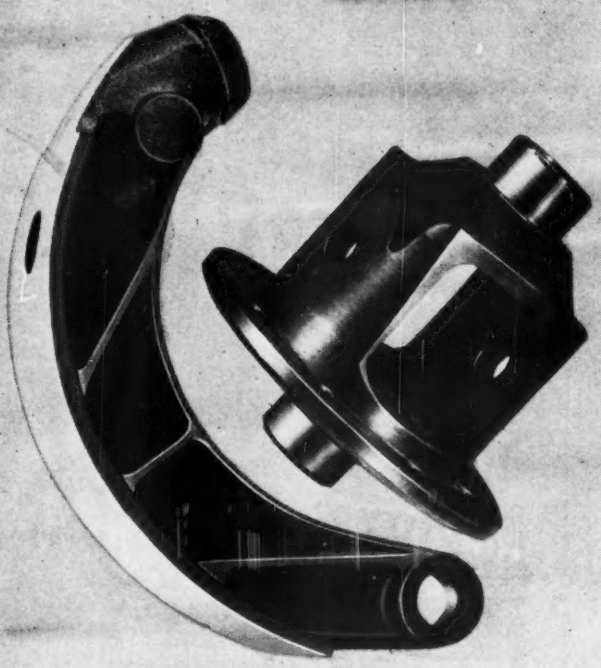
Gloucester Blackheart Malleable castings are widely used throughout the automobile, railway and farm machinery industries.

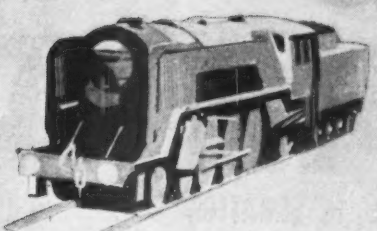
The new elevator-type electric furnace anneals in 48 hours! – instead of the usual 7 days. It also allows greater control of the component during annealing, resulting in uniformity of metal, greater strength and resistance to impact, and a smoother, finer skin. Machining time is therefore reduced to a minimum. Every heat is under constant laboratory control throughout the day and castings are rigidly inspected at every stage of production.

Gloucester technicians will gladly advise on the design of malleable or grey iron castings. Why not call them in at the drawing board stage?

Typical Gloucester Malleable specifications are:

Gloucester Blackheart Malleable		*Gloucester Lamellar Pearlitic Malleable*	
Elongation	18%	Elongation	5%
Yield Point	15 tons	Yield Point	22 tons
Tensile strength	25 tons p.s.i.	Tensile strength	35 tons p.s.i.





(right) Differential cage for motor vehicle in Malleable Iron.
(left) Brake Shoe in Malleable Iron.

GLOUCESTER FOUNDRY LTD., EMLYN WORKS, GLOUCESTER
(A subsidiary of the Gloucester Railway Carriage & Wagon Co. Ltd.)

GLOUCESTER
THE HOME OF
GOOD CASTINGS

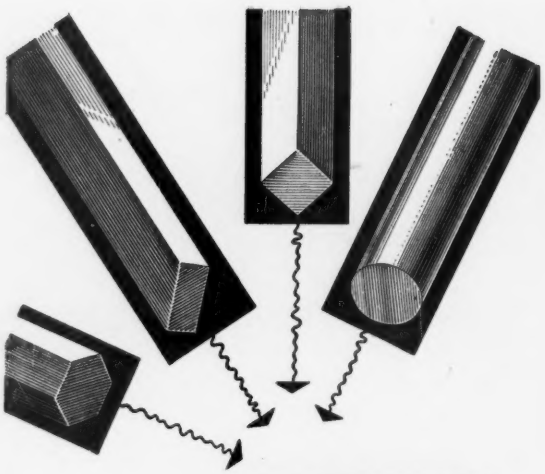
Telegrams: 'Pulleys' Gloucester
Telephone: Gloucester 23041

Nelson stands on his column

Intal stands on its own good name

INTAL

THE INTERNATIONAL TWIST DRILL CO. LTD.
INTAL WORKS · WATERY ST. · SHEFFIELD · 3
Telephone : 23072-3 Telegrams : Fluted, Sheffield
OBTAINABLE FROM YOUR STOCKIST
London Stocks : 16, ALDERSGATE ST., E.C.1.
Phone: MON. 3505
Glasgow Stocks : 50, WELLINGTON ST., C.2.
Phone: CITy 6994



quality in special purpose steel

DuneIt

ALLOY AND SPECIAL CARBON STEELS

Black rolled, bright drawn or smooth ground, in heat-treated or unheated conditions. Free cutting steels, heat-resisting steels, die steels, shear blade steels, high-speed tool steels, stainless steels, valve steels, hollow steel bars.

DUNFORD & ELLIOTT (SHEFFIELD) LTD.
Attercliffe Wharf Works, Sheffield 9.
Telephone: 41121 (5 lines). *Telegrams:* "Blooms, Sheffield, 9".
London Office: Linford Street, S.W.8.
Birmingham Office: 25 Burlington Chambers. 118, New St., 2

REDUCE *Your* CLEANING COSTS..

With HERMETIC **MUD FLAPS**

BEADED ON THREE SIDES. REINFORCED WITH 2 PLIES OF CANVAS THROUGHOUT, GIVING GREATER STRENGTH AND LONGER LIFE.

HERMETIC RUBBER CO. LTD.
HERMETIC WORKS · RYLAND ST · BIRMINGHAM 16
PHONE · EDGBASTON 0983/4 *Established 1895* GRAMS · HERMETIC, BIRMINGHAM

Fair Dinkum - it can take it . . .

. . . say these operators from down under

MEADOWS Diesels are more than a match for gruelling passenger vehicle operation, undertaken by the Melbourne — Brighton Bus Line of Australia. A MEADOWS 4DC330, recently removed for complete overhaul, gave over 140,000 miles of tough suburban work where its service would equal 12,000 hours. Bore wear was only .005" and crankshaft wear negligible. Similarly another 4DC330 is reported by the Progress Bus Line as giving over 130,000 miles of trouble-free service.

Proved in commercial service at home and abroad, the sound design and robust construction of MEADOWS diesels, result in greater mileage between overhauls, less down-time with more profit for the operator.

PERFORMANCE, RELIABILITY AND GREATER MILEAGE BETWEEN OVERHAULS IN COMMERCIAL AND PASSENGER VEHICLES

● Full details of the MEADOWS 4DC330 diesel engine for installation into most types of modern chassis, available from your local MEADOWS agent or direct from Henry Meadows Ltd.

MEADOWS DIESEL ENGINES AND GEARBOXES ARE BEST

POWER RANGE 36—270 B.H.P.

ASK THE MEN WHO DRIVE THEM

HENRY MEADOWS LIMITED AUTOMOTIVE DIVISION FALLINGS PARK · WOLVERHAMPTON · ENGLAND

Telephone : Wolverhampton 31921. Telegrams and Cables : OUTPUT, Wolverhampton
London Office : 37/41 Bedford Row, London, W.C.1. Holborn 6881/5

JSP MAD60

AN ASSOCIATED BRITISH ENGINEERING COMPANY

Six factors to cut running costs

- **HARD CHROME PLATED RING** *for long life & minimum bore wear.*
- **TURNED PERIPHERY RING, GRANODISED SURFACE** *for quick initial bedding to compensate the slower bedding expected with the chrome plated ring.*
- **INTERNALLY STEPPED RING, GRANODISED SURFACE** *a combined oil control and compression ring.*

- **"SEGVENT" OIL CONTROL RINGS :** *a high pressure ring in high grade DTD 485 iron, with a long efficient working life*

- **"FLEXIVENT" OIL CONTROL RING :** *(Reg'd Trade Mark No. 756949) with narrow lands and maximum possible venting for oil drainage. It is more flexible than the orthodox type of oil control ring, enabling the periphery to accommodate a considerable amount of bore wear or distortion.*
  Note the absence of heavy sections between the drain slots.
  Optional, tool finish, granodised or chrome plated.
- **All ring grooves deep anodically treated giving a wear resistant surface equal to a hardness value of 800/900 Brinell.**

This ring pack can be supplied with pistons without anodically treated ring grooves

Specialloid 'LONG-LIFE' PISTONS

ARE RECOMMENDED FOR ENGINES USING LOW VISCOSITY LUBRICATING OILS

SPECIALLOID LTD., BLACK BULL ST., LEEDS, 10. Tel. Leeds 31471/7

Special Purpose Machines

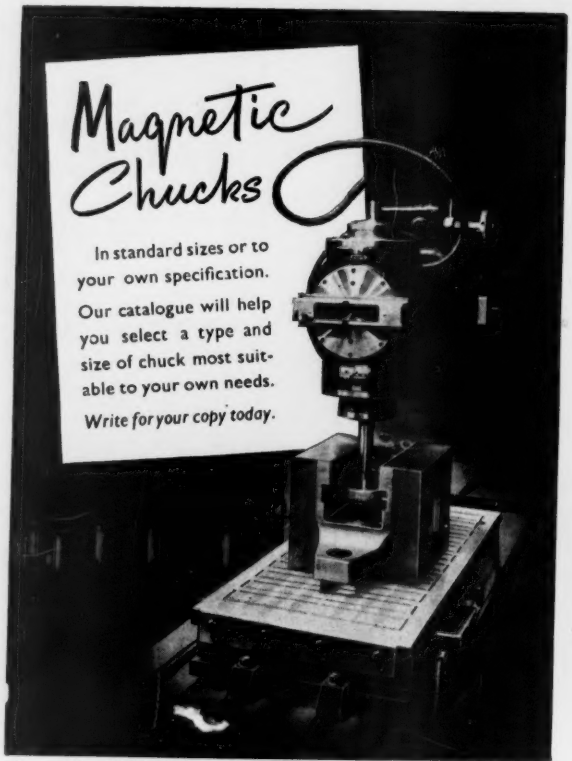
FAIRMAN PRECISION TOOLS AND PRODUCTS LIMITED

PRESS TOOLS
PROTOTYPES
MOULDS
GAUGES
JIGS, ETC.

'Phone : 3678

STATION RD (EAST), HORLEY, SURREY

A.I.D., M.O.S. AND ADMIRALTY APPROVED


Magnetic Chucks
In standard sizes or to your own specification.
Our catalogue will help you select a type and size of chuck most suitable to your own needs.
Write for your copy today.

J. H. HUMPHREYS & SONS LTD.
Blackriding Electrical Works, Wenerth, Oldham
'Phone : MAin 6067

DAWSON

flow-line cleaning

In this case the Dawson Automatic Cleaning and Degreasing Machine is installed at the end of a cylinder head machining line. The heads are rotated through high pressure jets of alkaline wash to ensure efficient cleaning and draining of all pockets.

Dawson equipment is built around any conveyor system for mass-production cleaning or can be supplied as cabinet types for batch work or occasional use. There are Rotary Drum types too for handling large quantities of small parts, automatically.

If you have a cleaning problem, write to Drummond-Asquith (Sales) Ltd., a Dawson machine can probably provide an efficient answer.

Sales & Service for . . . **DRUMMOND-ASQUITH** *. . . the British Isles*

DRUMMOND-ASQUITH (SALES) LTD., KING EDWARD HOUSE, NEW ST., BIRMINGHAM

'Phone : Midland 3431 (7 lines) 'Grams : Maxishape, B'ham. Also at LONDON : Phone : Trafalgar 7224 (5 lines) and GLASGOW : 'Phone : Central 3411

HF 210

Twenty-three years before "Coffee from Brazil"

Brazil today is the world's largest single coffee grower, yet her coffee industry only goes back to 1885 — twenty-three years after the Bank of London and South America opened its doors in Brazil. Since then, commerce with Latin America has increased enormously, and with it have grown the influence and interests of the Bank. Today, the Bank holds a unique position as the *only* British bank in Latin America. Up-to-date reports on local markets, trading regulations and general economic conditions are received regularly from Branches overseas and are summarised in the Bank's *Fortnightly Review*, which is distributed to customers and made available to those who have business in Latin America, Portugal or Spain

BANK OF LONDON
& SOUTH AMERICA LIMITED

HEAD OFFICE AND LONDON OFFICE:
6, 7 & 8 TOKENHOUSE YARD, LONDON, E.C.2
MANCHESTER: 36 CHARLOTTE STREET · BRADFORD: 55 WELL STREET
CONTINENTAL REPRESENTATIVE'S OFFICE: TALACKER 35, ZÜRICH

LET *US*
SPEED YOUR PROTOTYPES

Makers of Speedy Tooling for all types
EXPERIMENTAL WORK, PATTERNS, MODELS, JIGS, FORM TOOLS
IN ALL MATERIALS TO FACILITATE QUICK TURN ROUND WITH ECONOMY

★ **DESIGNING**
★ **KELLERING**
★ **TOOL MAKING**
★ **CASTINGS**

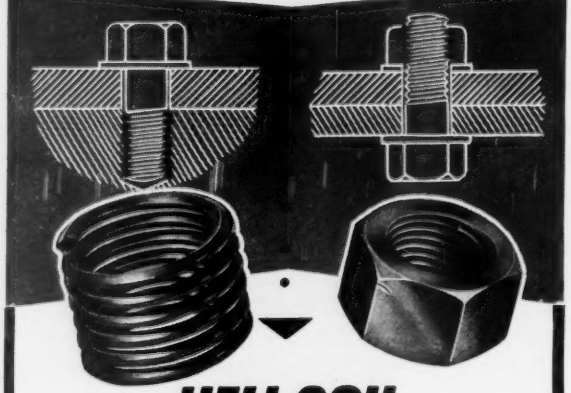
FOR MORE PERMANENT SCHEMES

Many years of experience with leading Aircraft and Automobile Manufacturers in this type of work

FINCH, WATSON LTD.
GREENGATES
ACCRINGTON
LANCS.
Tel: Accrington 5238 (2 lines)

For INCREASED DESIGN SCOPE, USE OF LIGHTER SECTION MATERIAL, HEAVY DUTY ASSEMBLY, FREEDOM FROM WEAR, CORROSION, STRIPPING & MOST OTHER THREAD TROUBLES . . .
You must have...

HELI-COIL REG'D TRADE MARK · **HELI-NUT**
SCREW THREAD INSERTS · HIGH ENDURANCE NUTS



HELI-COIL REG'D TRADE MARK

Manufactured by:
ARMSTRONG PATENTS CO. LTD · EASTGATE · BEVERLEY · YORKSHIRE

IT PAYS YOU TO
BUY MILLING CUTTERS
AT MAKERS PRICES

from

Clarkson
(ENGINEERS) LTD.

*Delivery by Return

Head Office and Works: NUNEATON

Branches at:
Newcastle · London · Birmingham · Bristol · Manchester · Glasgow · Belfast

THE BUSY BEE FROM G&C says:

One of the powers that bee—that's me

Mine is the power that drives much of the finest plant in this country — and the power behind some of the finest electrical appliances as well.

Install me in your factory and you'll find me one of the liveliest workers on the payroll. And if you sell powered machines put me in them also. Your customers will like to see my good name added to yours. *They* know a good fractional too!

G.E.C. Fractionals give you the advantage of famed G.E.C. reliability at no extra cost. They are available in all standard ratings and with a full range of mountings.

G.E.C.

Fractionals

THE GENERAL ELECTRIC CO. LTD., MAGNET HOUSE, KINGSWAY, LONDON, W.C.2

MINIRACK

Oscillographs

Photo by courtesy of the Principal, The Royal Aircraft Establishment Technical College

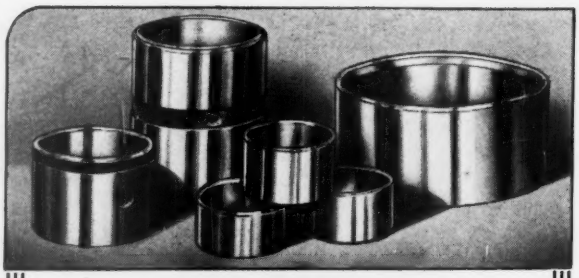
ME 109 ENGINE INDICATOR

This modern cathode-ray Engine Indicator manufactured by the Oscillograph Division of Southern Instruments Ltd., solves engineering and industrial problems by measuring transient pressure, force, strain, vibration, acceleration, and other physical qualities.

Please write for further details.

SOUTHERN INSTRUMENTS
OSCILLOGRAPH DIVISION

Proprietor: SOUTHERN INSTRUMENTS LTD.
CAMBERLEY • SURREY
Telephone No: Camberley 2230 (3 lines)
Telegraphic Address: Minrak, Camberley, England



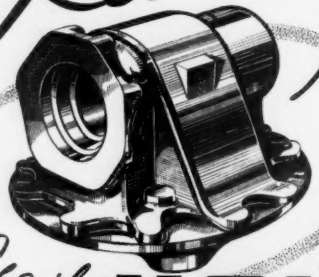
BUSHES

$\frac{3}{8}$" TO 10" BORE
HARDENED
AND
GROUND
ALSO
UNHARDENED
By
The Bush People
SEND US YOUR ENQUIRIES
Established 35 years

LAWRENCE Bros. MILLWARD LTD.
TELEPHONE WICKERSLEY 2041-2
ROTHERHAM

•IF YOU MUST HAVE

Reliability

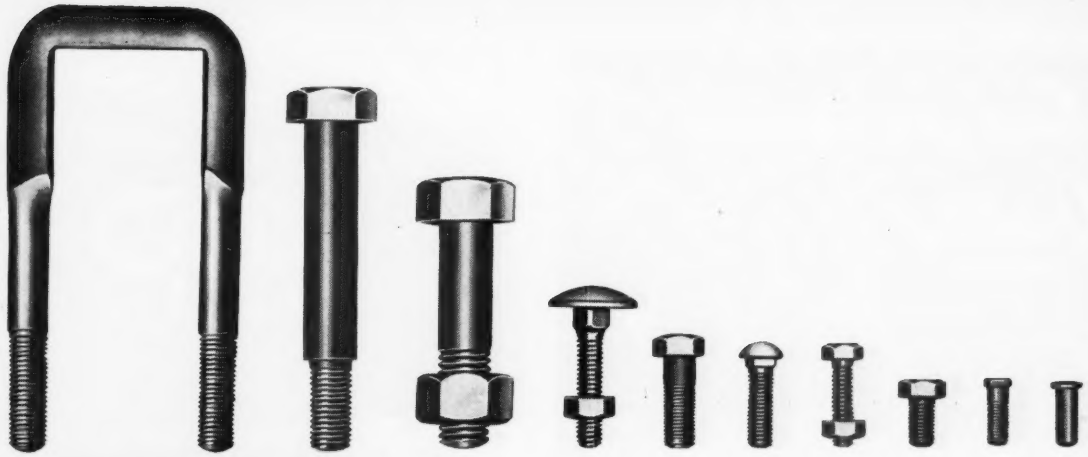


Specify **HALE**

Finest blackheart **MALLEABLE IRON CASTINGS**

SEND FOR DETAILS OF OUR FILM "MODERN MALLEABLE"

HALE & HALE (TIPTON) LIMITED DUDLEY PORT Staffs
GRAMS: MALLEBLE TIPTON PHONES: TIPTON 1671/5



WILEY

Whatever your fastening problem, Wiley can make a bolt for it—and a nut too—ask them !

make a bolt for it!

JAMES WILEY & SONS LIMITED, DARLASTON, STAFFS. *Telephone : James Bridge 2692.*

M-W.61

Britain's Roman Highways

ICKNIELD STREET

When the Romans invaded Britain they were faced with the problem of creating suitable highways which would give their legions access to the ends of the country. Of the many they built, the most important and famous were the Four Ways; Watling Street, The Fosse, Ermine Street and Icknield Street.

Icknield Street stretched from Norfolk to Southampton and is the one most likely to have been in existence at the time of Caesar's first invasion for it lacks directness, the first characteristic of a true Roman Road. It does not communicate with any ancient town but passes close to some prehistoric remains that are mostly British, such as the Berkshire White Horse and Stonehenge.

It winds from Chesterford through Dunstable, Wendover, along the Chilterns, crosses the Thames near Streatley, and runs on to the Ancient Temple at Avebury.

* Richard Berry have been actively concerned in improving the passage of vehicles over the roads of Britain and the World for over a hundred years. Today the tradition of their skilled craftsmen is being kept alive by the products of their new road spring factory.

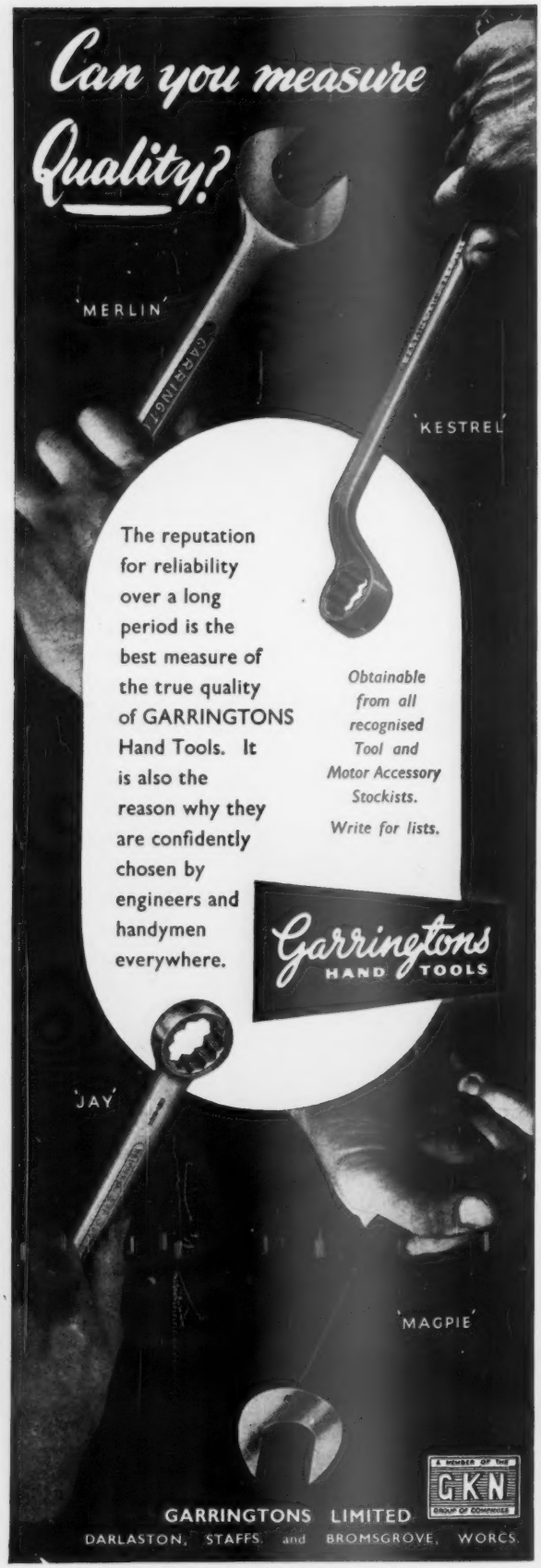
R B TRADE MARK

write for your copy of
"LEAF SPRING DESIGN"
by Alan Hodgson

CARRY ON BERRY

RICHARD BERRY & SON, WEST BROMWICH, STAFFS.
Tel: West Bromwich 1766-7-8.

ONE OF THE BROCKHOUSE COMPANIES



The reputation for reliability over a long period is the best measure of the true quality of GARRINGTONS Hand Tools. It is also the reason why they are confidently chosen by engineers and handymen everywhere.

Obtainable from all recognised Tool and Motor Accessory Stockists.

Write for lists.

Garringtons HAND TOOLS

GARRINGTONS LIMITED
DARLASTON, STAFFS. and BROMSGROVE, WORCS.

A MEMBER OF THE GKN GROUP OF COMPANIES

PLASTICS FOR INDUSTRY?

RMP

HAVE the experience AND the equipment

Compression and Injection Mouldings
Sawn and Machined Parts
PERSPEX and P.V.C. Mouldings
Laminated Tubes, Angles and Channels

RESINOID & MICA PRODUCTS LTD
MARY ST · BIRMINGHAM 12 · Tel Calthorpe 1303
LONDON 28 Queen Anne's Gate S.W.1 Tel WHitehall 8892
One of the group of companies associated with the Southern Areas Electric Corporation Limited

'LONDON' BRAND
TINNED & LEADCOATED STEEL SHEETS
for the automobile industry

'London' Brand are worth specifying by name because of their superior ductility and general working-up qualities. Direct delivery in our own vehicles to all parts of Great Britain ensures that loads arrive on time and in perfect condition. Stocked by leading Merchants.

Illustrated brochure of useful data sent on request. Write for your copy to-day.

SHIMWELL & Co LTD
MANUFACTURERS SINCE 1875
WELLINGTON ROAD · LEYTON · LONDON · E.10
Tel: LEYtonstone 2281-2

SUPPLIED TO MANUFACTURERS ALL OVER THE WORLD

Manufacturers of—

- BRIGHT STEEL & BRASS TURNED & CHAMFERED WASHERS.
- PLAIN BRIGHT STEEL & BRASS WASHERS.
- STEEL & BRASS B.A. WASHERS.
- ROOFING WASHERS.
- ENGINEERS' BLACK WASHERS.
- Odd Sizes a Speciality!

CHARLES (WEDNESBURY) LIMITED

BRIDGE WORKS · WEDNESBURY · STAFFS.

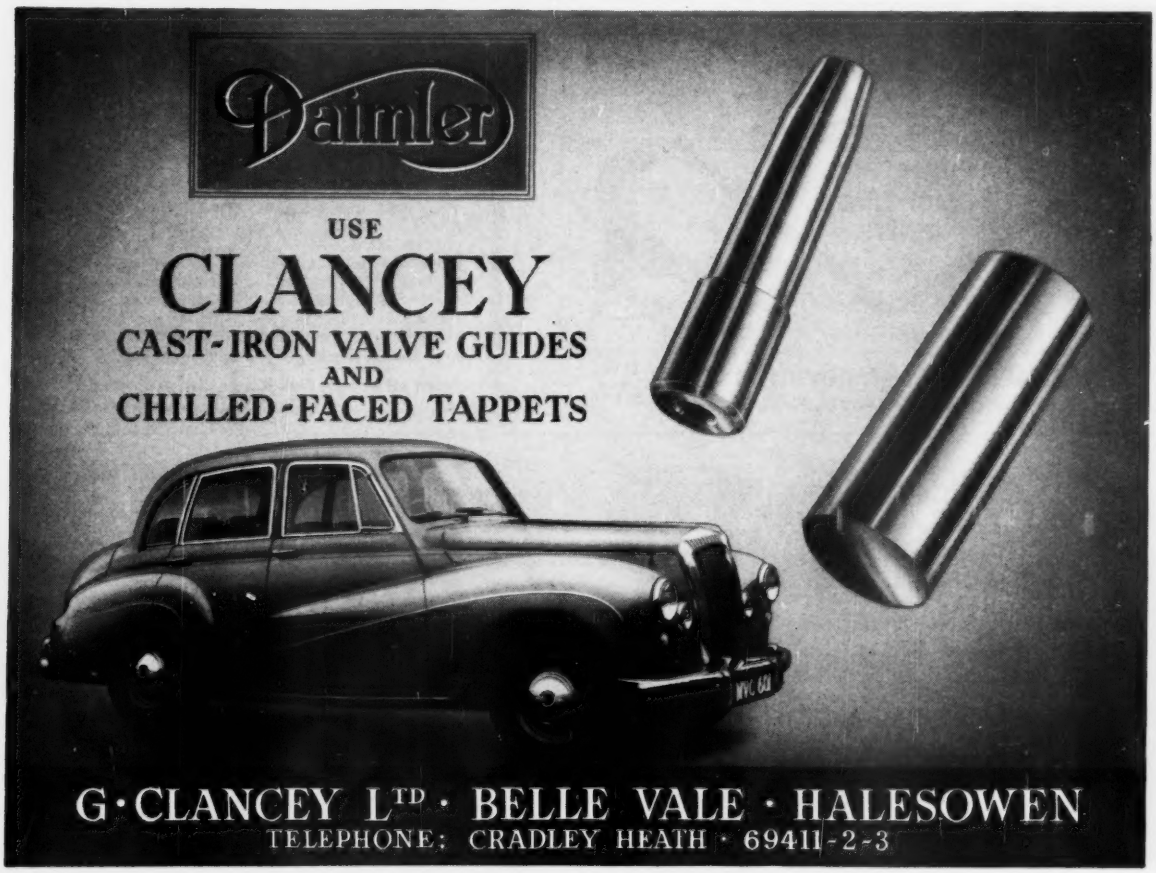
Telephone: WEDnesbury 0564-5 Telegraphic Address: "CHAMFER, WEDNESBURY"

Daimler

USE

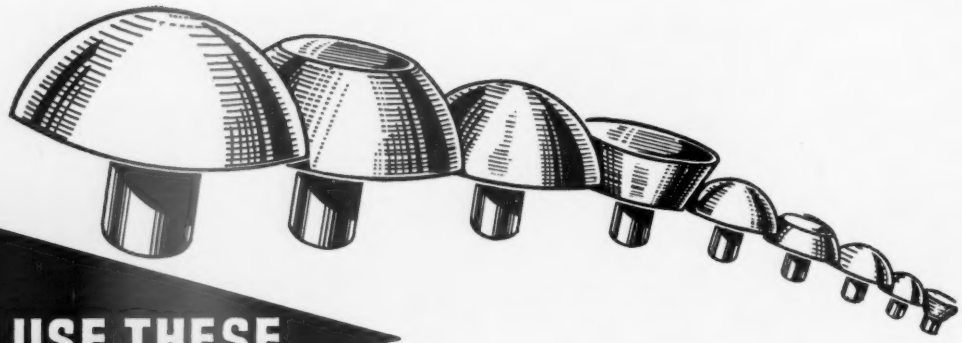
CLANCEY

CAST-IRON VALVE GUIDES AND CHILLED-FACED TAPPETS

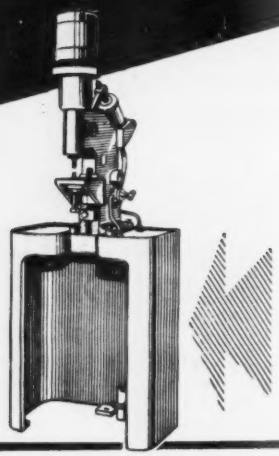


G·CLANCEY LTD · BELLE VALE · HALESOWEN

TELEPHONE: CRADLEY HEATH · 69411-2-3



IF YOU USE THESE



We make the widest range of rivet spinners on the market. They are universally used in the manufacture of every type of component for the Automobile Industry, especially where a neat appearance is as important as a well-formed head. Send us a sample of the product you make and we will advise you on the best machine for the job

YOU NEED THIS

Illustrated: The RS3. VMD A.E. $\frac{3}{16}$ in. cap. air-operated machine on cabinet base.

TURNER
MACHINE TOOLS LTD
63-68, PRINCIP ST., BIRMINGHAM, 4

Tel: Aston Cross 2244.

MEKELITE

GEARED JOINT

INDUSTRIAL LIGHTING UNITS

For wall, bench or machine mounting. *Catalogue sent free on request*

MEK-ELEK Engineering Ltd.
17, Western Road MITCHAM, Surrey MITcham 3072

---

the motor vehicle

fifth edition

By K. Newton, MC, BSc, ACGI, AMinstCE, MIMechE and W. Steeds, OBE, BSc, ACGI, MIMechE. This book covers recent advances in automobile design, including engines, transmissions, axles, brakes, steering, suspension and chassis details. Both petrol and diesel engines are covered and the present state of the gas turbine as applied to road vehicles is considered. Non-technical language is used, the book providing an accurate straightforward explanation of automobile engineering theory.

from all booksellers 42s net by post 43s 6d

Iliffe & Sons Ltd., Dorset House, Stamford St., London, S.E.1

---

(3)

3M COATED ABRASIVES

FEATURE THE SELF-CONFORMING "PG" WHEEL

This 3M innovation solves many difficult polishing problems and is exclusive to the 3M system.

Only 3M provide Demonstration Centres run by qualified engineers. You can see for yourself, without cost, how time can be saved and a better finish achieved. 3M abrasives do a better job.

THE MINNESOTA MINING & MANUFACTURING CO. LTD.

Birmingham: East 2051 London: Temple Bar 6363 Manchester Central 1351 Glasgow: City 6704

5 POINTS THAT MAKE TURQUOISE THE PERFECT PENCIL

PRECISION GRADING
Never is there any deviation from the precision of Turquoise grading. 4H means 4F and will give you exactly the line you require from it every time. Each of the 17 degrees of grading is compounded from a separate precisely controlled basic formula.

SUPER SMOOTHNESS
Always silky smooth a Turquoise eases your work. No flaws to spoil your line or paper. The 100% Electronic Graphite cleansed and refined to particles of 1/25,000th inch results in a smoother, more compact lead.

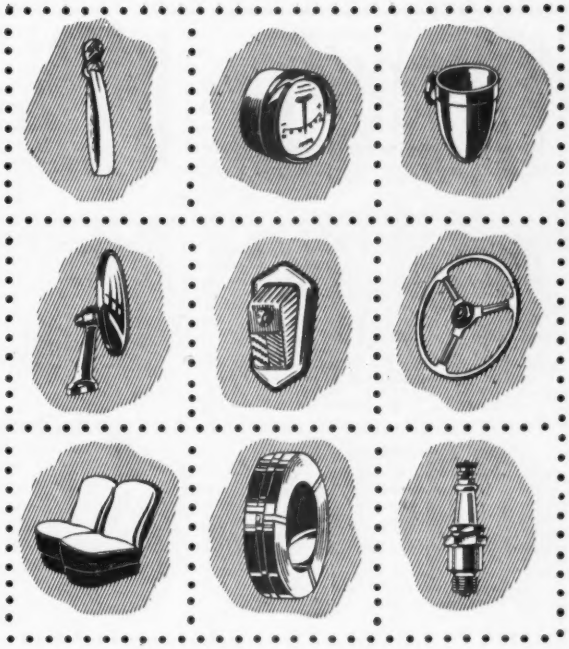
POINT STRENGTH
The superior point strength of Turquoise saves time and money. The more compact structure has reduced point breakage to the minimum. Nor will a Turquoise lead snap inside the wood because Eagle super-bonding welds lead to wood in one inseparable unit.

SUPERIOR OPACITY
Notice how crisp and uniformly black are the lines you draw with a Turquoise. 100% Electronic Graphite again. The finer lead structure deposits lines of even density, so that you can rely on clear reproductions with no faint lines or omissions.

DURABILITY
Finally, the 100% Electronic Graphite makes Turquoise leads so durable that the longest line remains uniform in width and blackness throughout its entire length. You can prove this for yourself by examining the longest line you draw through a magnifying glass.

EAGLE
'CHEMI-SEALED' *Super-bonded*
TURQUOISE
DRAWING PENCILS
with **100% 'ELECTRONIC'** *Graphite*
T10

EAGLE PENCIL COMPANY, ASHLEY ROAD, TOTTENHAM, N.17



Find the car Bumper in this picture

Find the Habershon steel strip and you've found the bumper . . . it's just one of the innumerable applications of this vital material in the automobile industry.

For over a century we have produced hot and cold rolled strip and sheet to the most exacting specifications. Modern high-speed production methods enable us to produce the quantity you need at the quality for which we are famous. We welcome your most exacting specifications.

You can't get away from it

Habershon

STEEL STRIP

means quality in quantity

J. J. Habershon & Sons Ltd., Rotherham. Tel. 2081 (6 lines).

OA/3449

AUTOMOBILE ENGINEER

CLASSIFIED ADVERTISEMENTS

RATE 4d. PER WORD. MINIMUM 4/-

Each paragraph charged separately. Box number 5 words—plus 1/-. Advertisements for the May, 1957, issue should be to hand not later than first post 23rd April

(No responsibility accepted for errors)

MACHINERY FOR SALE

FOUR Magee No. 10 Automatic Wiring and Edging Machines for sale. Capacity: minimum 24 S.W.G. sheet and 10 S.W.G. wire; maximum 14 S.W.G. sheet and ¼" wire or 16 S.W.G. sheet and 5/16" wire. Two rates of feed, 6' and 18' per min. Treadle clutch. Motor drive for 400/3/50. Photo. F. J. Edwards Ltd., 359 Euston Road, London N.W.1. {5565

NEW "Niagara" No. 192 Swaging Machine for sale. Hand geared operation, with rolls. Capacity 18 g. Gap 13¼". Photo, etc., from F. J. Edwards Ltd., 359 Euston Road, London, N.W.1. {5567

PATENTS

THE Proprietor of British Patent No. 701623, entitled "Improvements in Spring Suspension for Vehicles," offers same for licence or otherwise to ensure its practical working in Great Britain. Enquiries to Singer, Stern & Carlberg, Chrysler Building, New York 17, N.Y., U.S.A. {5561

THE Proprietor of British Patent No. 700846, entitled "Valve Seat Insert Construction for Internal Combusion Engine," offers same for licence or otherwise to ensure practical working in Great Britain. Enquiries to Singer, Stern & Carlberg, 14 E. Jackson Blvd., Chicago 4, Illinois, U.S.A. {5560

SITUATIONS VACANT

CAR Project Engineer. An assistant project engineer is required by The Rover Co. Ltd., Lode Lane, Solihull. This is an opportunity to work on a new car project and the successful applicant will be offered a salary commensurate with experience. The Company operate a Staff Contributory Pension scheme. Interested applicants are invited to apply in confidence, with full particulars of experience and personal details, to the Labour Manager. {5564

DO not reply to this advertisement unless you are a Qualified Professional Engineer and wish to make Research and Development your career.

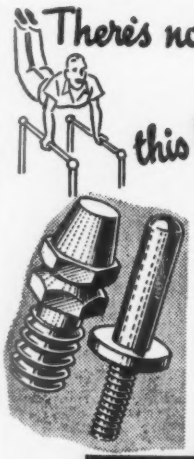
THERE are several vacancies in the Research Department of a leading Birfield Company for engineers who are corporate members of the Institution of Mechanical Engineers, have served a full engineering apprenticeship, preferably in the automobile industry, and have also had wide experience in Research and Development work.

IN addition, there is also a vacancy for a Designer Draughtsman, who has gained considerable experience in an Engineering Department or Development Drawing Office and has obtained Higher National Certificate in Mechanical Engineering.

THE Research Department is situated at the new Chester Road Factory of Hardy Spicer Limited and the work is of an extremely interesting and varied nature embodying development of new products and components, together with Research and Development in connection with a number of the activities associated with the Birfield Group of Companies.

WRITE to the Personnel Director, Hardy Spicer Limited (Dept. 7), Erdington, Birmingham, 24. {5566

THE MONOTYPE CORPORATION LIMITED, Redhill, Surrey, require a Senior Designer Draughtsman, whose main duty would be to check the accuracy and tolerances of working drawings made in a Design and Development Department. The work is technically interesting and previous experience in similar position in the Automobile, Aircraft or Machine Tool industries would be an asset. This is a permanent position carrying a good salary for the right applicant. Please apply, in writing, with age and full details of career, to the Chief Designer. {5558



For automatic and capstan precision parts—in any metal—to your own specification . . . consult the specialist machinists.

I.F.V., D.A.I., D.I.Arm., A.R.B. Fully approved.

PRECISION PARTS *from the* BAR *by* M C L

M.C.L. & REPETITION LTD

POOL LANE - LANGLEY - BIRMINGHAM

Telephone: Broadwell 1115 (4 lines) and 1757

DEVELOPMENT ENGINEER/ CHIEF DRAUGHTSMAN

required for well known International Firm in North-East England.

Applicants should hold A.M.I.Mech.E. or equivalent and should have experience in design of MEDIUM SIZED EARTH MOVING AND MINING EQUIPMENT for Batch Production.

The successful applicant will be responsible to the Managing Director.

Please apply in writing, giving full details, which will be treated in confidence, to Managing Director, Box 7489.

SITUATIONS VACANT

ASSISTANT to Chief Designer required with experience in the layout of Commercial Vehicle Chassis. Consideration given to older draughtsman with practical experience. Projects in hand offer scope for initiative with small old-established Company. Salary according to experience. Box 7445, c/o Automobile Engineer. {5568

DESIGNER-DRAUGHTSMAN, to work in small team, in ideal surroundings, on a variety of interesting new development projects. Preferably with some experience of the design requirements for production of automotive or similar components.

SALARY—£1,000 p.a. Pension Scheme.

APPLY by writing only to Moulton Developments Ltd., Bradford-on-Avon, Wilts. {5569

APPLICATIONS are invited for pensionable posts as Examiners in the Patent Office to undertake the official scientific, technical and legal work in connection with Patent applications.

AGE at least 21 and under 35 years on 1st January, 1957, with extension for regular Forces' service.

CANDIDATES must have (or obtain in 1957) 1st or 2nd Class Honours in Physics, Organic or Inorganic Chemistry, Mechanical or Electrical Engineering or in Mathematics, or an equivalent qualification, or have achieved a professional qualification, e.g. A.M.I.C.E., A.M.I.Mech.E., A.M.I.E.E., A.R.I.C. For a limited number of vacancies, candidates with 1st or 2nd Class Honours degrees in other subjects—scientific or otherwise—will be considered. Exceptionally, candidates otherwise qualified by high professional attainments will be considered.

STARTING pay for 5-day week of 42 hours in London between £605 and £1,120 (men), according to post-graduate (or equivalent) experience and National Service. Maximum of scale £1,345. Women's pay above £605 slightly lower, but is being raised to reach equality with men's in 1961. Good prospects of promotion to Senior Examiner, rising to £2,000 (under review), and reasonable expectation of further promotion to Principal Examiner.

APPLICATION form and further particulars from Civil Service Commission, Scientific Branch, 30 Old Burlington Street, London, W.1, quoting S 128/57 and stating date of birth.

INTERVIEW Boards will sit at intervals, as required. Early application is advised. {5563

SERVICES OFFERED

DESIGN Office Capacity available for Mechanical and Production Engineering. Special Machines and Projects. Norris Brothers Ltd., 53 Victoria Street, London, S.W.1. Tel.: Abbey 5444. {5546

TUITION

TECHNICAL Training in Automobile Engineering. Practical home-study courses conducted by post. Guaranteed coaching for Inst.Mech.E. (Automobile Div.), etc. Write for free book: International Correspondence Schools Ltd., Dept. CL.36, Kingsway, London, W.C.2. {5540

A.M.I.M.I., City and Guilds, A.M.I.Mech.E., etc., on "No Pass-No Fee" terms. Over 95% successes. For details of Exams and Courses in all branches of Auto., Aero, Mechanical Eng., etc., write for 144 page handbook — Free. B.I.E.T. (Dept. 643), 29 Wright's Lane, London, W.8. {5553

SHEET METAL MACHINERY • MACHINE TOOLS • WOODWORKING MACHINERY

ALL TYPES — NEW & USED. ASK for LISTS.

F. J. Edwards Ltd

EDWARDS HOUSE, 359-361, EUSTON RD., LONDON N.W.1

Phones: EUSton 4681 & 3771

and Lansdowne House 41, Water St., Birmingham, 3 (CENtral 7606-7)

Cost Accounting and the Engineer

By Kenneth B. Mitchell, A.C.W.A., AFF.I.W.M.

This book sets out to explain cost accounting and how it operates to the engineer on the shop floor. The approach is simple and direct, the reader being shown in a practical manner how modern cost accounting influences every department. Special attention is given to problems of budgeting and budgetary control.

CONTENTS

Part I. Introduction to costing: Accounting for materials and labour: Overhead expenses: Final costing and presentation: Costing by standards, etc.

Part II. The purpose of budgets: Key budgets: Material and labour budgets: Expense, administrative and master budgets: Budgetary control, etc.

10s. 6d. net. *By Post* 11s. 2d.

Obtainable from booksellers or direct from:—

Iliffe & Sons Limited, Dorset House, Stamford Street, London, S.E.1

BOLTS & NUTS

MARSDEN

MANCHESTER 1

Samuel Marsden & Son Ltd. Ard 1765.

COTTON BAGS

FOR SPARE PARTS Etc.

Walter H. Feltham & Son Ltd

Imperial Works, Tower Bridge Road
Telephone: HOP 1784 LONDON, S.E.1

BOOKS

GAS Welding and Cutting: A Practical Guide to the Best Techniques. By C. G. Bainbridge. M.I.Mech.E., M.Inst.W. A comprehensive text-book providing practical information on almost the whole range of available gas welding and cutting equipment, methods and processes. Invaluable to the practical welder as well as to those responsible for gas welding and cutting operations involved in the fabrication and repair of industrial equipment. Price 15s. net. By post 15s. 9d. From all booksellers or from The Publishing Dept., Dorset House, Stamford Street. London, S.E.1.

MATERIAL Handling in Works Stores. 2nd Edition. By L. J. Hoefkens. Shows how the use of fork-lift trucks and pallets in industrial stores can increase production, utilize floor space more effectively, help control of movement and reduce costs. Includes a description of a system actually operated in a modern factory. 18s. 0d. net from all booksellers. By post 18s. 10d. from The Publishing Dept., Dorset House, Stamford Street, London, S.E.1.

AUTOMOBILE Chassis Design. 2nd Edition. By R. Dean-Averns. A text-book on the fundamentals and technique of design for heavy and light vehicles. This greatly enlarged edition covers all the main components of an automobile apart from the prime mover. 30s. net from all booksellers. By post 31s. from The Publishing Dept., Dorset House, Stamford St., London, S.E.1.

ABACS or Nomograms. By A. Giet. Translated from the French by H. D. Phippen and J. W. Head. Most engineers have made use of nomograms at some time in their careers, and are fully alive to the fact that they are a very convenient tool when the same formula has to be solved repeatedly for several sets of variables. It is fair to say, however, that only a small proportion of even those who habitually employ nomograms know how to construct them for their own use. Most of the comparatively small literature on the subject is written for mathematicians and is extremely difficult for the practical engineer to comprehend. This book is essentially practical, and not only demonstrates the many and varied applications of the abac or nomogram, but shows how even those without highly specialized mathematical knowledge may construct their own charts. 35s. 0d. net. From all booksellers. By post 35s. 10d. From the publishers: Iliffe & Sons Ltd., Dorset House, Stamford Street, London, S.E.1.

STEELS in Modern Industry: A Comprehensive Survey by 29 Specialist Contributors. General Editor W. E. Benbow. An invaluable guide for engineers, designers and draughtsmen; it specifies the steels best used in various engineering applications (bearing in mind the present need for economy), describes their general and special properties and characteristics, and how they may be surface finished for anti-corrosive and other purposes. 42s. net, from all booksellers. By post 43s. 6d. from The Publishing Dept., Dorset House, Stamford Street, London, S.E.1.

OXYGEN Cutting: A Comprehensive Study of Modern Practice in Manual and Machine Cutting. By E. Seymour Semper, M.I.Mech.E., M.Inst.W. Written to assist engineers concerned with cutting and shaping material, this book describes many of the machines designed for various applications of oxygen cutting to template with multiple heads and also the actual methods of operation. Price 10s. 6d. net. By post 11s. 2d. From all booksellers or from The Publishing Dept., Dorset House, Stamford Street, London, S.E.1.

INDUSTRIAL Brazing. By H. R. Brooker and E. V. Beatson, B.Sc.(Eng.), A.M.I.E.E. The first full-length study of this subject. Covers in detail all modern brazing methods, including torch, furnace, high-frequency induction, resistance, salt bath and dip, with chapters on the special techniques necessary for aluminium, stainless steels, beryllium copper, cemented carbides and vacuum tube construction. 35s. net from all booksellers. By post 36s. 6d. from The Publishing Dept., Dorset House, Stamford St., London, S.E.1.

SERVICING Guide to British Motor Vehicles. Vol. III. Presents in a standardized form for easy reference, servicing and maintenance information, data, sectional arrangement drawings and diagrams on many British cars, commercial vehicles and tractors from 1953 to 1955, arranged by makes and fully indexed. Includes an illustrated glossary of terms used and a list of alternative part names, a collection of useful and unusual conversion tables is given as an appendix. 50s. 0d. net. By post 52s. 0d. Vol. II covers many popular 1951-52 British models, the information being presented in the same style as in Volume III. 42s. 0d. net. 44s. 0d. by post. Supplies of Vol. I are still available, containing details of 52 post-war British cars, commercial vehicles and tractors. 63s. 0d. net. By post 65s. 6d. Available from all booksellers or direct from Trader Publishing Co. Ltd., Dorset House, Stamford St., London, S.E.1.

Wilmot Breeden Laboratories

DEVELOPMENT DESIGNERS & ENGINEERS

•

DEVELOPMENT DESIGNERS
Vacancies exist for Senior Designers in the Research and Development Division. The Division covers a wide range of light engineering including Mechanisms Development, Test Equipment, etc.

DEVELOPMENT ENGINEERS
The Research and Development Division also has vacancies for Graduates or persons with equivalent qualifications in Mechanical Engineering, Physics, Mathematics. The posts involve work on a wide range of problems: Analyses and Design of Mechanisms, Stress Analyses, Resonance and Analyses of Motion, Spring Design, Optical Developments, etc. Experience is desirable but not essential.

The Research and Development Division is located in ideal surroundings at Umberslade Park, near Hockley Heath. Working conditions and prospects are excellent; transport is provided to and from the Establishment.

The posts carry monthly staff status, good salaries, staff pension scheme, etc.

Applications, which will be treated in strict confidence, should state age and full details of qualifications and experience, and be addressed to :

Chief Development Engineer,
Research & Development Division,
WILMOT BREEDEN LABORATORIES,
Umberslade Park, Solihull,
Warwickshire.

Springs

should be lively too!

LEAVE IT TO
Lewis
OF REDDITCH
SPRINGS, SPRING CLIPS
PRESSWORK, WIRE FORMS
VOLUTE SPRINGS

A Lewis Spring is lively, resilient, always ready to give as good as it gets for twenty-four hours a day. To make sure that you always have the right spring for the right job you should have our 40-page manual, choc-full of technical data and only 2/6d post free.

LEWIS SPRING CO. LIMITED — RESILIENT WORKS, REDDITCH
'Phone Redditch 720/1/2
London Office: 122 High Holborn W.C.1 'Phone Holborn 7479 and 7470

INDEX TO ADVERTISEMENTS

	PAGE
AC-Delco Division of General Motors Ltd.	76
Adamant Engineering Co. Ltd.	61
Aerialite Ltd.	12
Aircraft-Marine Products (Gt. Britain) Ltd.	53
Aluminium Bronze Co. Ltd.	82
Amal Ltd.	112
Andre Rubber Co. Ltd.	49
Angus, George, & Co. Ltd.	74
Archdale, James, & Co. Ltd.	107
Armstrong Patents Ltd.	118
Artrite Resins Ltd.	51
Atlas Copco AB	Cover ii
Automotive Products Co. Ltd.	5, 6, 7, 8
Bank of London & South America Ltd.	118
Barber & Colman Ltd.	110
Birfield Industries Ltd.	11
Birmetals Ltd.	87
Borg-Warner Ltd. (Morse Chain Div.)	48
Box No. 7489	126
British Electrical Development Association	10
British Oxygen Co. Ltd., The	52
British Piston Ring Co. Ltd., The	75
British Plastics Exhibition	23
"British Plastics Year Book"	90
Brown, David, Corporation (Sales) Ltd., The	3
B.S.A. Tools Ltd.	Cover iv
Burton Griffiths & Co. Ltd.	Cover iv
Bury Felt Mfg. Co.	95
Bury, Richard, & Son Ltd.	121
Bushing Co. Ltd., The	38
Cape Asbestos Co. Ltd., The	16, 17
C.A.V. Ltd.	68
Charles (Wednesbury) Ltd.	123
Churchill, Charles, & Co. Ltd.	104
Clancey, G., Ltd.	123
Clarkson (Engineers) Ltd	119
Clayton Dewandre Co. Ltd.	18
Consolidated Pneumatic Tool Co. Ltd.	Cover iii
Cooper & Co. (Birmingham) Ltd.	102
Cooper's Mechanical Joints Ltd.	42
Copper & Asbestos Washer Co. Ltd.	104
Cork Mfg. Co. Ltd.	77
Cross Mfg. Co. (1938) Ltd.	106
Dartmouth Auto Castings Ltd.	64
Deloro Stellite Ltd.	100
Desoutter Bros. Ltd.	9
Doncaster, Daniel, & Sons Ltd.	93
Dowty Seals Ltd.	92
Drummond - Asquith (Sales) Ltd.	117
Dunford & Elliott (Sheffield) Ltd.	114
Dunlop Rubber Co. Ltd.	28
Eagle Pencil Co.	125
Edwards, F. J., Ltd.	126
Electric Furnace Co.	36
E.N.V. Engineering Co. Ltd.	109
Fairman Precision Tools & Products Ltd.	116
Farnborough Engineering Co. Ltd.	21
Feeny & Johnson Ltd.	110
Feltham, Walter H., & Sons Ltd.	127
Fenner, J. H., & Co. Ltd.	4
Ferodo Ltd.	40, 41
Finch Watson Ltd.	118
Foden Ltd.	108
Fry's Metal Foundries Ltd.	88
Fuller Gear Boxes	32
Fuller, Horsey, Sons & Cassell	88
Funditor Ltd.	46
Garringtons Ltd.	122
General Electric Co. Ltd., The	119
Gill's Cables Ltd.	106
Girling Ltd.	58
Gloucester Foundry Ltd.	113
Gordon & Gotch Ltd.	86
Griffiths, Gilbart, Lloyd & Co. Ltd.	102
Habershon, J. J., & Sons Ltd.	125
Hale & Hale (Tipton) Ltd.	120
Hardy Spicer & Co. Ltd.	45
Harper, John, & Co. Ltd.	26
Herbert, Alfred, Ltd.	71
Hermetic Rubber Co. Ltd.	114
Hey Engineering Co. Ltd.	90
High Duty Alloys Ltd.	59
Hoffmann Manufacturing Co. Ltd., The	81
Holroyd, John, & Co. Ltd.	103
Humphreys, J. H., & Sons Ltd.	116
I.C.I. (Billingham) Ltd.	39
I.C.I. (General Chemicals, Heat Treatment) Ltd.	65
I.C. (Marston Excelsior) Ltd.	86
I.C.I. (Metals) Ltd.	31
Ilford Ltd.	27
International Twist Drill Co. Ltd., The	114
Jackson, H., Ltd.	73
Johnson & Johnson (Great Britain) Ltd.	112
Kirkstall Forge Eng. Ltd.	25, 47
Lawrence Bros. Millward Ltd.	120
Laycock Engineering Co. Ltd.	13
Lee, Arthur, & Sons Ltd.	22
Lench's (Birmingham) Ltd.	112
Lewis Spring Co. Ltd., The	128
Lincoln Electric Co. Ltd.	15
Linread Ltd.	2
Litchfield Bros. Ltd.	92
Manganese Bronze & Brass Co. Ltd., The	67
Marsden, Samuel, & Son Ltd.	127
M.C.L. & Repetition Ltd.	126
Meadows, Henry, Ltd.	115
Mek-Elek Engineering Ltd.	124
Metalastik Ltd.	37
Metropolitan-Vickers Electrical Co. Ltd.	34
Midland Motor Cylinder Co. Ltd., The	78
Minnesota Mining & Manufacturing Co. Ltd.	124
Morris, B. O., Ltd.	111
Moss Gear Co. Ltd.	96
"Motor Vehicle, The"	124
Neill, Jas., & Co. (Sheffield) Ltd.	82
Newall, A. P., & Co. Ltd.	24
Norgren, C. A., Ltd.	94
Osborn, Samuel, & Co. Ltd.	44
Park Gate Iron & Steel Co. Ltd., The	70
Perry Barr Metal Co. Ltd.	35
Philidas Div. of Whitehouse Ind. Ltd.	55
Pioneer Oilsealing & Moulding Co. Ltd.	97
Plessey Co. Ltd., The	63
Pollard Bearings Ltd.	14
Prestons Ltd.	106
Ransome & Marles Bearing Co. Ltd.	50
Renold Chains Ltd.	84
Resinoid & Mica Products Ltd.	122
Rockwell Machine Tool Co. Ltd.	29
Rubber Bonders Ltd.	56
Salter, Geo., & Co. Ltd.	33
Sentinel (Shrewsbury) Ltd.	101
Sheffield Twist Drill & Steel Co. Ltd., The	Cover i
Sherborne Rubber Co. Ltd., The	84
Shimwell & Co. Ltd.	122
Silentbloc Ltd.	19
Simmonds Aerocessories Ltd.	105
Skefko Ball Bearing Co. Ltd.	80
Smethwick Drop Forgings Ltd.	54
Southern Instruments Ltd.	120
Specialloid Ltd.	116
Spencer & Halstead Ltd.	108
Spencer, H. F., & Co. Ltd.	43
Sterling Metals Ltd.	62
Super Oil Seals & Gaskets Ltd.	20
Terry, Herbert, & Sons Ltd.	60
T.I. Aluminium Ltd.	91
Tilghman's Ltd.	98
Town, Frederick, & Sons Ltd.	94
Tucker, George, Eyelet Co. Ltd.	98
Turner Bros. Asbestos Co. Ltd.	66
Turner Machine Tools Ltd.	124
Udal, J. P., Ltd.	108
Vaughan, A. J., & Co. (Mitre Works) Ltd.	110
Vaughan Associates Ltd.	85
Vaughan Bros. (Drop Forgings) Ltd.	96
Vaughan, Edgar, & Co. Ltd.	99
Vokes Ltd.	30
Wakefield-Dick Industrial Oils Ltd.	83
Ward, T. W., Ltd.	72
Wellworthy Piston Rings Ltd.	100
Whittaker Hall & Co. (1929) Ltd.	89
Wickman Ltd.	1
Wild-Barfield Electric Furnaces Ltd.	57
Wiley, James, & Sons Ltd.	121
Wilmot Breeden Ltd.	127
Zinc Alloy Die Casters Association	69

Printed in Great Britain for the Publishers, ILIFFE & SONS LTD., Dorset House, Stamford Street, London, S.E.1, by James Cond Ltd., Charlotte Street, Birmingham 3. "Automobile Engineer" can be obtained abroad from the following: AUSTRALIA & NEW ZEALAND: Gordon & Gotch Ltd. INDIA: A. H. Wheeler & Co. CANADA: The Wm. Dawson Subscription Service Ltd.; Gordon & Gotch Ltd. SOUTH AFRICA: Central News Agency Ltd.; Wm. Dawson & Sons (S.A.) Ltd. UNITED STATES: Eastern News Co. Entered as Second Class Matter at the New York, U.S.A., Post Office.

This is the
C.P.
IMPACT WRENCH
Model 344-RS

IT CUTS OPERATING TIME FROM MINUTES TO SECONDS

CONSOLIDATED PNEUMATIC MAKE OVER 480 DIFFERENT MODELS OF POWER TOOLS

Whether running up ¼" nuts in thousands on light assembly or driving 1¾" nuts on heavy construction work, there's a C.P. pneumatic Impact Wrench to drastically reduce the time and costs of the job. The patented impact clutch eliminates torque reaction and the final torque obtained can be accurately controlled by pressure regulation. There's no twisting thrust or kickback when nuts are fully seated. To this speed and efficiency, then add versatility. C.P. Impact Wrenches are available in 6 sizes and can also be used for tapping, stud-setting, screwdriving, drilling or reaming. Ask for the Impact Wrench section of Catalogue No. 50.

Consolidated Pneumatic

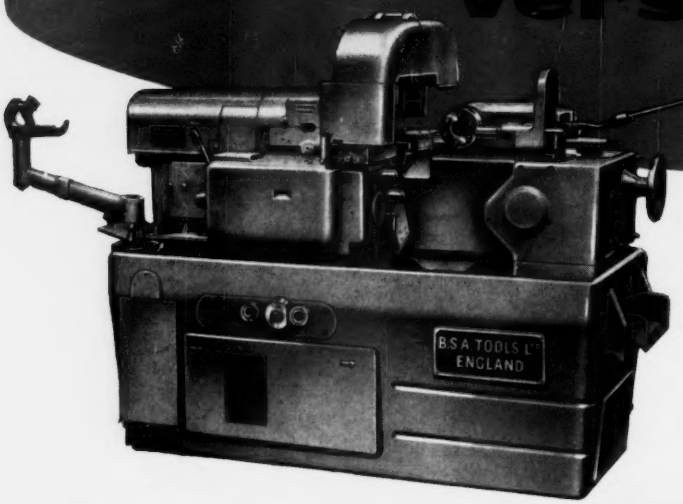
CP105

CONSOLIDATED PNEUMATIC TOOL CO., LTD., 232 DAWES ROAD, LONDON, S.W.6

AIR COMPRESSORS · PNEUMATIC TOOLS · ELECTRIC TOOLS · CONTRACTORS EQUIPMENT · ROCK DRILLS · PUMPS · DIAMOND DRILLS

versatile

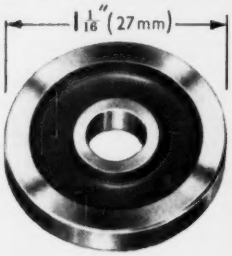
B·S·A



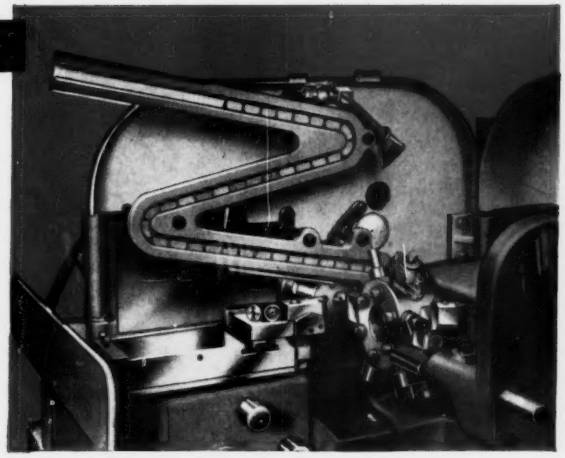
Many problems involved in the high-rate production of work of special nature or requirement are being solved by B.S.A. single spindle automatics. For work up to 2 in. diameter, from the commonplace to the most intricate, B.S.A. automatics maintain their reputation for speed with accuracy and reliability.

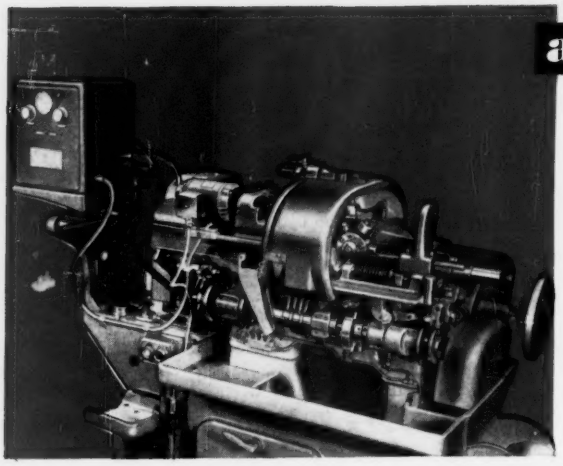
magazine loading

This bronze component is machined complete in 7 seconds on a B.S.A. 98 single spindle automatic. The "hairpin" magazine feeds the cast-blank to a loading block on the rear cross slide whence it is transferred to a chuck. Ten operations are performed involving tooling on the front cross slide, the turret and a stationary cutter within the workspindle, then the finished part is automatically released to fall in the pan.



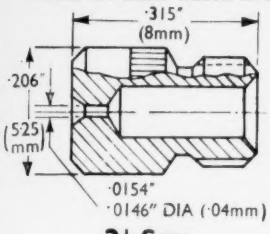
7 Secs





automatic inspection

Standard tooling on a B.S.A. 48 single spindle automatic produces this burner-jet in 3¼ seconds. Included in the sequence of operations is an electro-pneumatic means of automatic inspection of the fine hole. Any obstruction to an air-blast which is directed through the component causes a back pressure to be fed to a Sigma control unit. This operates a solenoid unit which stops the machine and lights an indicator. Drill replacement and removal of the defective component can then be made.



3¼ Secs

409

Also B.S.A. METRIC 18-52 mm. single spindle automatics for users of continental specification machines

B.S.A. TOOLS LIMITED · BIRMINGHAM 33 · ENGLAND

Sole Agents in Great Britain:
BURTON GRIFFITHS & CO LTD KITTS GREEN BIRMINGHAM Telephone STEchford 3071

TRADE MARKS
B·S·A TOOLS GROUP